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THE BIRD LOVER AS A SCIENTIST.

By O. G. LIBBY.

The extraordinary growth of interest in nature study in this country has had a marked effect not only on pedagogy and all related subjects but also upon biology and its allied sciences. The investigations of the zoölogists, especially, are being enriched by the labors of a large number of enthusiastic and wholly unrecognized amateurs. In the field of bird study there are many problems that escape the trained zoölogist, familiar only with prescribed routine of manual and laboratory. But the bird lover has at least one advantage over the scientist, he is in touch with the bird on the human side, he sees in this form of animal life the acme of the intellectual and the artistic combined. Where the biologist is scientific, the bird lover is sympathetic.

This gives the latter a considerable advantage, for, while he may acquire the requisite technical skill in order to study his favorite subject more scientifically and still keep his sympathetic touch unimpaired, the scientist can never reach this close relation by the road of the dissecting room and the microscope. It is then to the amateurs, and not to the scientists, as a class, that the teaching world owes much of the new impulse in the direction of bird study. For a student who lays aside his manual and attempts the difficult task of conducting a class in bird study out of doors with living forms for material, there comes a disagreeable surprise on finding out that, after all, our knowledge of birds is exceedingly limited and very inexact. Problem after problem will arise in actual observation for the solution of which there is little or no help to be found in the printed accounts. Take the single case of the color changes in the plumage of the bobolink, the scarlet tan-

ager, the orchard oriole or the redstart. Has any observer yet been able to state just how the transformations take place, when and where? In the case of the orchard oriole and the scarlet tanager the changes extend through a period of nearly three years. One would suppose that if the scientists who study fish and reptiles could have the patience to count the scales for the different species, that some scientist would have undertaken the task of counting the feathers for the different species of birds. Yet if this were seriously proposed at a meeting of scientists, there is no doubt but that it would be laughed at. We may hope, sometime, to see the amateur, whose time is of no value, take pains to count the feathers on the different species of common birds and carefully tabulate them by the various feather tracts of the skin, making a separate study of the varying proportions of colored to uncolored feathers. The value of the results reached will then be recognized by the scientist and the study will be pushed to its logical outcome.

When this is done we shall know, as we cannot now, the effect of climate, food and locality upon a bird's feathers, both as to number and texture. This will, perhaps, supply the most effective means of determining whether our winter birds migrate and whether those we see here during January are from the north. In the problems of evolution, this feather counting would give a means of ascertaining exactly how far individual variation could proceed within the limits of the species and along what lines of feather development this variation proceeds.

Wallace has pointed out that among individuals of the same species of birds there is great diversity in the measurements. Following this suggestion the writer made a careful study of one species, the common red winged blackbird. Twenty-four measurements were taken for each bird and about sixty birds were measured. The accompanying plates indicate the range of the diversity, in twenty of the whole number measured. Eight sets of measurements were selected and the table below indicates the character of these measurements.

TABLE I.

I. Length of intestine.
II. Extent of wings from tip to tip.
III. Length of body from end of beak to tip of tail.
IV. Length of wing.
V. Length of esophagus.
VI. Length from clavicle at tip of breast-bone to the cleft of the lower mandible.
VII. Length of tail.
VIII. Length of head.

If these sets are compared it will be seen that no one bird exceeds in all but rather that each bird has some noticeable proportion of measurements which differentiates it from all others. In some the tail or wing, is longest, in others the body or head. Whatever the particular environment calls for in the evolution of new habits or characteristics is thus to be found in some of the individuals of a medium sized flock. The fittest that survive are the ones who possess among other things that peculiar proportion of measurements which adapts it to the new demands of food-getting or escape from enemies.

An excellent illustration of this partial evolution of a species from the habits and proportions of one family into another totally different is to be found in the warbler family. The black and white creeper has lost a large number of his original warbler characteristics and has taken on those of the woodpecker. This appears in the color, in the lengthened beak, the flattened body, and in the method of locomotion. A still better illustration is the Louisiana water thrush. This bird frequents the banks of streams, and gets its food after the fashion and in the same places as does the snipe. As a result the color is a fair imitation of that of the snipe, both above and below; the beak is longer and the body is larger than that of the average warbler and its habit of flying up to a low bush or overhanging limb when alarmed tells the nature of its enemies. But most characteristic of all, this warbler has the gait of the snipe, even to the tilting motion of the body. From a tiny brilliantly colored acrobat of the treetops there has evolved a plump sober-colored snipe-like creature whose markings and motions are all the results of the new environment.

The variation of proportions in the measurements shown in the plates may not indicate that evolution of other forms is still going on but it certainly points back to a time when species was more flexible and readily developed along whatever line seemed to offer the least resistance. But evidence of variation among individuals of a species may be found outside mere physical characteristics. One of the most enjoyable features in bird study is the song. In this almost wholly unworked field, where there is so much to discover, it has already been pointed out that the amount of individual variation in a given species is sometimes extraordinary. Such well known singers as the field sparrow, the American goldfinch, the song sparrow and the meadow lark furnish examples of this kind of variation.

Thirty-five songs for the field sparrow, and twenty for the song sparrow have been reported, and to any one at all familiar with the vocal performances of these birds, this will not seem at all unusual. White throated sparrows show surprising individual variation in their rather long and characteristic song.

The Baltimore oriole is still another singer of great capabilities and wide range of variation. Indeed the oriole seems to me to make the nearest approach of any of our birds to the sounds in human speech. On the occasion of a wheel trip from Wisconsin to the northeastern portion of Ohio the writer was struck by the local variation in bird songs. The vesper sparrow, for instance, in Ohio, began his song with the two notes of the chickadee's song. The swamp blackbirds were noticeably different, also, and so were the meadow-larks. There is no doubt an opportunity here for some amateur who has the musical training to discover and make use of what has so long lain unknown and unused.

Another interesting question arises in connection with the time when young birds learn to sing. The period of song varies so much with different species that no fixed rule seems to prevail. It is sometimes possible, also, by observing the singers in a given species to ascertain how long it takes for the young males to assume the full male plumage. One illustration will suffice;—a purple finch in female plumage was found singing the full spring song, which would seem to indicate that it takes two years for the species to assume the male plumage. Songs and calls are the language of birds, and by this means all the emotions find expression and thought is conveyed. In the works of Thompson-Seton the language of animals is very cleverly used in a series of charming sketches, and though the author too often calls upon his imagination to eke out his facts, yet there is a sufficiently substantial basis to his tales to make them excellent interpretations of nature. Some years ago the writer assisted on the relief work in a city which had been devastated by a cyclone. The most painful experience that remained after two weeks' work among the horrible debris of the ruined homes was to hear for several mornings at daybreak the pitiful song of a Baltimore oriole whose nest, eggs and dead mate were picked up near the house. Since that time the motif of this song has been identified with a very effective strain in a funeral march written by Grieg.

The most marvellous phenomenon in bird life beyond all question is the semi-annual migration. The numbers of the birds, the distance travelled and the dangers and difficulties to be encountered all contribute to make this a notable performance. But, in spite of its importance, bird migration has received comparatively little attention in America. There are three ways in which this movement may be studied. First we may keep note of all arrivals and departures day by day and thus ascertain dates for successive years. If there are observers enough to cover a given region fairly well, a good summary of the whole movement may be worked out. This for

the most part is the only method by which migration has so far been studied. Some reports have been made relative to the destruction of birds at lighthouses, but no one has yet studied migration at these danger points with a view of recording the exact number of species and individuals for every month in the year. From some acquaintance with lighthouse keepers it seems certain that if the government would supply these men with such a manual as Chapman's, many valuable records could be kept by them. Certainly the lighthouse keeper is the most natural observer to be selected to keep account of the loss of life at his station and most of them would do this willingly if they knew it would be of service to any one. Such monuments as the one at Bunker Hill and the Washington monument frequently attract migrating birds in cloudy or foggy weather, small flocks of such birds may often be heard calling about the tops of these structures. Along the Appalachian mountain mass the coke ovens that burn all night also prove attractive to migrants. These ovens throw a broad band of light upwards to the clouds. When the migrating birds reach this light they turn downward and are often found fluttering about the fires by the watchmen there. Those observers who have access to such places as these should preserve a record of those birds that have been deflected from their course by delusive lights.

A second method of observing migration lays emphasis upon the calls of the passing birds, their number, direction and character.

In the fall of 1894 my attention was attracted by the calls of a certain species of birds passing overhead during several nights in middle September. There was an unmistakable family resemblance in these calls as the migrating birds came trooping out from the north, making the spaces of the upper air ring with their mellow calls. Now and then this merry chorus would contain a discordant note of a bird of another species showing that other birds were mingled in the great swarm headed southward. This particular flight continued for three nights, all cloudy and very dark. The line of flight seemed to extend to the westward and to lose itself in the distance.

While such observations appeal to the scientist they have meanings also to the bird lover. There is something weird in these high-pitched calls sounding down out of the upper darkness. They seem to express by turns, fear, doubt, hope or confidence. Sometimes the call is complex and like that of the young rose-breasted grosbeak expresses the first bewilderment of the fledgling, thrust out into unfamiliar surroundings and winging his way amid utter darkness, guided only by the cries of his fellows. But besides the charming naïvete of the mellow

call of this grosbeak, it seems to express also, that light-hearted optimism which sustains the whole bird family during the trials and dangers of their semi-annual flight. One could wish for that knowledge of the language of animals in which Mowgli of the Jungle Stories is so well versed and which Aaron of the Wildwoods teaches to Buster John and Sweetest Susan. With such a gift of understanding, the favored mortal seated beneath the hurrying stream of migrating birds far above him, could translate the myriad sounds into messages marvellous and unique, full of strange adventure and hair-breadth escape, telling of far-away lands and myriads of well-hid nests, of life on the water along solitary beaches or amid the unbroken stillness of the vast pine forest; messages redolent with perfume of tropical flower jungles, glowing with the fresh eager life of a new spring, overflowing with delight at the long flights over ocean, mountain and wide-spreading plain. Yet this wonderfully tangled mesh of sound that descends upon us out of the sky does not hold us spellbound and mute till the marvel has passed by; it comes to the busy and indifferent multitude unheeded. Every year over the crowded streets of busy cities float these feathered multitudes, but their loud cries of wonder and fear as they descry the lights below them find few listeners in the hurrying throng. We are so immersed in our bustling existence that the very messages from heaven make no impression upon us. Birds are especially noisy on foggy or rainy nights. On several occasions during the May migration at Madison have severe thunderstorms caught a large flock of migrants and sent them scurrying down by hundreds all over the city. The piteous cries of these wet and bewildered birds heard amid all the noises of the storm sufficiently express to a sympathetic listener their utterly disconsolate condition. One might almost imagine them to be a train load of drowsy but indignant travellers spilled out of their comfortable places by an accident and seeking by devious and unpleasant ways the dubious hospitality of a near-by village.

A detailed observation of the calls of birds during the night was made Sept. 14, 1896, at Madison on a small elevation southwest of the city. The sky was clear, there was no moon, and a raw southeast wind was blowing. The total number of calls counted between ten and three o'clock was about thirty-eight hundred, or an average of twelve per minute. As in 1894, the mass of sound seemed to lie toward the west, which would make the general direction of flight from northeast toward the southwest. Though the observation extended from ten till a little past three the calls began much earlier in the evening and kept up long after four. A great variety of birds passed

overhead during this evening and in all sorts of groups or flocks. Sometimes the lines of birds would seem to extend for more than a mile in perfect formation, as indicated by the regular calls up and down the whole line. At other times smaller squads of more swiftly flying birds would dash by overhead keeping up the compact formation with the precision of trained cavalry.

This method of observing bird migration is not difficult and it has the great advantage of being open to every one. The best time to observe is in May and September, and cloudy or foggy nights yield the best results. It is possible, nevertheless, to hear the calls of passing birds as early as the latter part of August and they do not cease even into November. As late as Thanksgiving, in the latitude of St. Paul, Minn., a large number of calls were recorded between nine o'clock and midnight. Regular observations covering a month each year, even if limited to a single hour in the night, would soon come to have a great scientific value. In a subject so little studied, every one is a discoverer and all observations are of value if made with care.

One valuable conclusion was reached by this study of nocturnal flight. It has been repeatedly alleged that captive birds are attacked in the spring and fall by fits of restlessness, which lead them to beat their wings against their cages in vain endeavors to escape. This has been adduced by careless observers as a proof of the migratory instinct. But like most of the facts upon which the hypothesis of instinct rests, this one has been misinterpreted. The captive bird hears the calls of his own species during their semi-annual flights and very naturally tries to escape to join them. The duller human hearing of his captors entirely misses the sounds which to him are full of meaning, and his efforts are considered as proving the existence of a blind impulse termed instinct.

A third method of studying migration consists in observing the birds as they pass across the face of the moon. In this method a small telescope is necessary or a good surveyor's instrument. In this way it is very easy to take leisurely observations of a very wonderful phenomenon. The birds are visible on the disc of light from one-tenth to one-third of a second for the rapid flyers and for the slower ones they are sometimes visible two or three seconds. The first record made was during the nights of September 11, 12 and 13, 1897. The telescope used belonged to the Washburn Observatory and was a small six-inch instrument. A total of five hundred and eighty-three birds were counted in the three evenings which, it was estimated by Prof. A. S. Flint, represented 168,000 birds passing Madison within range of the telescope. This will give some

faint idea of the nature of the movement a portion of which passes under one's eye in so short a space of time. The first conclusion reached by these observations was that the bulk of the birds used but a small portion of the night for flight. Plate III shows graphically at what hour most of the birds are on the wing. The apex of the movement is seen to be attained at 10.30, and in less than an hour later the flight has largely passed. That the record shows birds flying as late as five in the morning indicates, as we should expect, that the different species fly for different lengths of time, the strong-winged birds keeping up their flight much later than those weak flyers. It is also to be noted from the chart that the birds move in waves, passing successively over a given region. This is in harmony with observations taken by every other method and is indeed one of the better known facts about bird migration. It was further observed that the birds did not all take one direction, but it was not until several years later that other records were placed with these and a satisfactory conclusion reached. From plate IV is seen indicated the direction of flight for each bird across the moon's face; the more heavily shaded portion of the line being that portion of the field at which the bird passed out of sight. If the predominant direction of flight for August and September be compared it will be noticed that they are at right angles to each other, and it will be seen further, from the principal directions of flight in the spring, that the flight in May corresponds in direction to that in September while that in April corresponds to that in August. Whatever astronomical errors may have been made in reducing the directions across the moon to earth directions, it still remains a fact that in the spring and fall there are two well defined lines of flight at right angles to each other and that the later one in the spring corresponds to the one in September. Different directions in flight mean different routes, and this would seem to indicate different species of birds and to suggest a variety of routes to correspond with the great differences in point of wing-power, food, enemies and intelligence among the large number of species that migrate. The migration thus becomes an immensely complicated process having all possibilities for individual or species variation which is afforded by any other of the vital activities in bird life. A further study of the figures in the plate will show that in each of the months there is evidence of birds of another month. For instance, in the figure showing directions of flight for May will also be seen a considerable number of lines having the direction which was found to be the predominant one in April, and this will be found true in every one of the figures in the plate. In other words the May birds begin their flight in their own direction as early as April. We know this

is true from other observation; the myrtle warbler comes early, while the bulk of the warblers come in the middle of May. But still another conclusion may be drawn from the material shown in these figures. While the great majority of the birds followed one general direction there were a considerable number of scattering flights recorded. These undoubtedly represent lost birds who are wandering in every direction seeking their missing comrades. The dotted lines in the figures represent the track of lost birds who changed their course within range of observation. In every case it will be noticed that the dotted line points along some general route as it leaves the circle, indicating that this records the flight of a bird that had wandered away from the flock and was just rejoining his companions or those of his own species.

This evidence of wandering on the part of migrating birds even when there is a full moon serves as a striking proof that it is no mere impulse that drives birds on the long semi-annual journeys. We have seen that birds do wander in cloudy or foggy weather, especially during storms. But here is visual proof that a certain number of them wander out of their course in a great variety of directions. What then becomes of the hypothesis of an unvarying instinct that guides the birds as gravitation holds the stars in their courses? For this theory to be true there ought to be no wandering or lost birds either on clear or cloudy nights. That there are such birds continually present, the records of every observation for the past five years abundantly prove. Only a beginning has been made in the study of the nocturnal flight of birds but it is a subject that promises well for the amateur and will yield the scientist a rich return as soon as he can be convinced it is worth his while.

For the present a few observers are doing the work for the mere pleasure of it. None of those who aided in gathering the material presented in this paper could restrain their exclamations of delight or astonishment as the birds floated leisurely into sight or dashed pell mell across the little circle of light. There was constant evidence of the highest activity and steady purpose in the perpetual come and go of the moving birds, and upon turning the eyes away from this busy scene to the quiet moonlit landscape as it lay in midnight hush outside, the contrast was striking in the extreme. Those who participated in the labor of observation all felt that what had so long remained securely hidden from us, had at last yielded itself to cross-section study of the most approved scientific type. But it was no less a peep into fairy land as well, to watch the tiny hurrying forms flit silently across the charmed circle that rendered them visible to mortal gaze.

The rate at which the birds moved was very much affected by

the wind. Numbers were recorded as seeming to be blown along with hardly an effort, while others sailed, occasionally flapping their wings and apparently borne on by a strong current of air. One bird was noted in particular since it passed slowly *backward* across the moon, evidently too tired to struggle longer against the wind. The identification of the birds seen was not possible in most cases. Gulls and swans were observed at different times as were also ducks and geese. There were identified a large number of swamp blackbirds, some meadowlarks, a night heron, some robins, a night-hawk and a sparrow-hawk. A number of very small birds were recorded as passing "like a shot" and were probably either swifts or swallows. It is claimed that many strong-winged species of birds migrate only by day, but as most of these have been observed through the telescope at night, this theory, also, must yield to the recorded fact.

In view of the continual presence of such birds as gulls, ducks and geese at night, migrating with the rest, their migration by day seems a little hypothetical. While it is true such birds move about a good deal during the day in search of food, there has never been a set of observations in this country which has proved day flight as persistent as it has been demonstrated to be during the night. Nocturnal migration seems to prevail throughout the bird world and for the best of reasons. As the birds move out of their accustomed haunts into new regions, food-getting becomes a serious problem especially since the motive power of flight must be supplied by such food as can be found in a strange land among unknown dangers. Daylight alone would render such search for food safe and certain for the hungry birds whose long flight the previous evening had left exhausted and in great need of refreshment. Night time is better for migration in large flocks since the danger of attacks from hawks and shrikes is greatly lessened. That they see the general configuration of the country is certain, and the stars and moon also guides them as well. Foggy nights, while not interfering at all with a hypothetically perfect instinct of direction, do make it hard for birds to find their way since they have not the infallible guide which it is fabled that they possess. Great physical features like river valleys, mountain ranges and coast lines are the guide lines of bird migration, and at their distance above the earth, the whole lies in perfect panorama beneath them as they fly. In this country the fly lines for our birds are the Atlantic coast lines, the Appalachian Mountain mass, the Mississippi River, the Great Lakes, the Rocky Mountain and coast ranges and the Pacific coast. Particular points along these lines are specially dangerous to migrants. The lighthouse at Key West, in Florida,

stands at a place where all the birds from Maine to Georgia pass by as well as those that inhabit the higher regions of the Appalachians. After severe storms at this lighthouse thousands of dead birds lie piled at the base of the tower. Another danger is the lighthouse at Mackinaw Strait between Lake Michigan and Lake Huron. Here are concentrated all the lines of flight from the upper shores of the lakes and from all the interior waters of Canada.

It would render the lighthouses much less dangerous to migrating birds if the lights were changed from the fixed to the alternating form. The keepers at Minot Ledge say that when this lighthouse had a fixed light a large number of the birds flying from Cape Ann to Cape Cod or the reverse were blown inshore and dashed against the tower by the strong northeast gales. Now that the light is an alternating one, the birds are able to avoid it when they are driven in by a storm and so escape death. Another fruitful source of disaster to migrating birds is the old-fashioned electric tower or mast which places a light or a group of them high in the air above the city. For lighting purposes they are quite useless but they will remain a menace to birds till they finally give way to more modern and less expensive modes of lighting.

Observation of nocturnal migration in the manner described, and records of the number and kind of birds killed at coke ovens, tall monuments, lighthouses, and electric towers will in time form a body of material of the utmost value to the student of bird life. Such facts are worth numberless theories and will help to dissipate much of the pseudo-scientific half-truth which is so prevalent in the popular works and hurriedly prepared manuals. We are just coming to realize how extremely ignorant the best informed are on so fundamental a question as migration. Until the omnipresent scientist occupies this field and drives out the amateurs, there is unlimited opportunity for discoveries of the highest importance; a golden harvest to be reaped by the unpaid enthusiast.

In the economy of bird life, migration plays an extremely important part. As a factor in the evolution of a perfect bird, one best adapted to its environment, migration must ever be considered as holding a high place. No weakling can survive the tremendous strain of the long journey southward from the nesting places into countries all unknown to the thousands of young birds. The stragglers drop out by the way or are picked up by the attendant hawks and shrikes that skirt the flanks and harrass the rear of the bird armies, and by spring-time it is the pick and flower of the year's product that find their way safely northward to select the choicest spots and rear their young for the next trial trip. Survival of the fittest has a

meaning in this supreme test of wing power and lung capacity, of courage and prudence and indomitable perseverance. Again, migration serves to scatter and redistribute the various groups of individuals. In this way new feeding grounds are discovered and different species are more widely extended or take possession of more suitable breeding places. This process goes on so thoroughly that in spite of a considerable return of individuals to the same spot year after year, a pretty complete rearrangement of the bird population from the spring and fall migrations certainly takes place. In ten years' observation no year has been quite like any other either in the number of individuals in a given species or in the variety of the species observed. Each year seemed to be distinctive and marked off from all others, and the more complete the record the clearer was the evidence upon this point. An artesian well, sunk in a treeless Dakota prairie, poured its surplus water into a neighboring depression, producing a small lake. It was not three months old before the migrating birds discovered it and made it a stopping place on their way. As time went on and grass and shrubs grew thickly along its edge, the birds took possession of it and it became a populous oasis in a desert. Tall trees and thick undergrowth now mark the spot where the lake lies and it has become the home of hundreds of birds of many species, while from it as a center birds disperse in all directions during the season of migration. If the source of the water should fail the peopling of this spot would cease and the birds would soon learn to avoid the place where water and vegetation were fast disappearing. This is but a single instance of hundreds of similar cases, but it serves to illustrate one of the functions of migration in the economy of nature. In brief it is this that gives to our bird population the extreme of flexibility by which it adapts itself with the utmost ease to the great changes wrought in the face of the country during the past few hundred years. Of all the agents of change and destruction man has been the chief. Since his occupation of America a number of birds have made notable changes in their habits and so have become in a certain sense the companions of man.

The cliff swallows have abandoned the overhanging rocks where they built their flask-shaped nests, and under the eaves of barns they now build shallow saucer-shaped nests, where food is more abundant. The robins and phœbes have taken to living in nests often supported on man-made structures. Even the night-hawks rear their young on the gravel-covered roofs of the Chicago "sky scrapers" and gather their food above the smoke and dust of her streets. The chipping sparrow has now become the *hairbird*, and for a large part of her nest material uses the horse hair which she obtains by means

of her association with man. The warbling vireo and wood pewee have become our common city birds in the parks and along the drives. The only common name of one of our birds has come from the association with our cattle, the well-known cowbird.

In this very brief sketch but a few of the interesting and unsolved problems of bird life have been indicated. There are many more that will instantly occur to every one. It is a matter of encouragement, also, to the unscientific bird lover that he has still most of the field to himself. In this most fascinating study some of the deeper problems of animal life are involved. No one need feel that the subject is unworthy his serious attention. On the side either of science or of the humanities, it is exceedingly rich. Especially are the teachers and students of psychology bound to recognize the possibilities here and make increasing use of them in the future.

PLATE I.

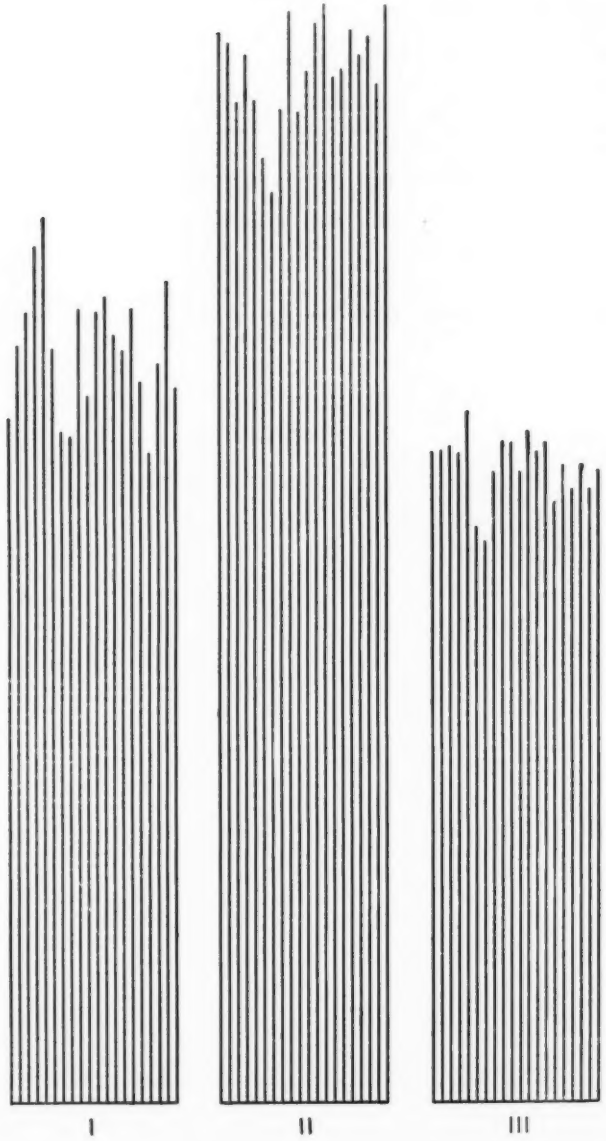


PLATE II.

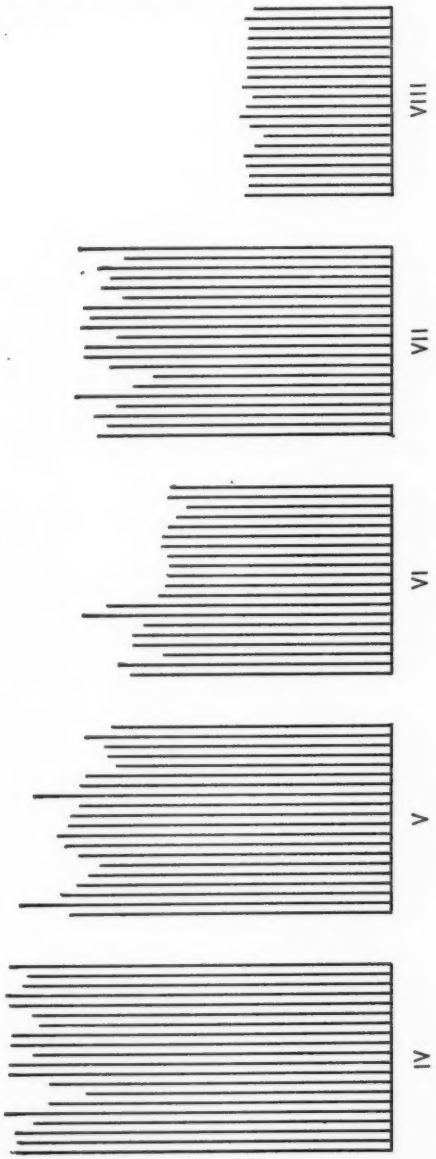
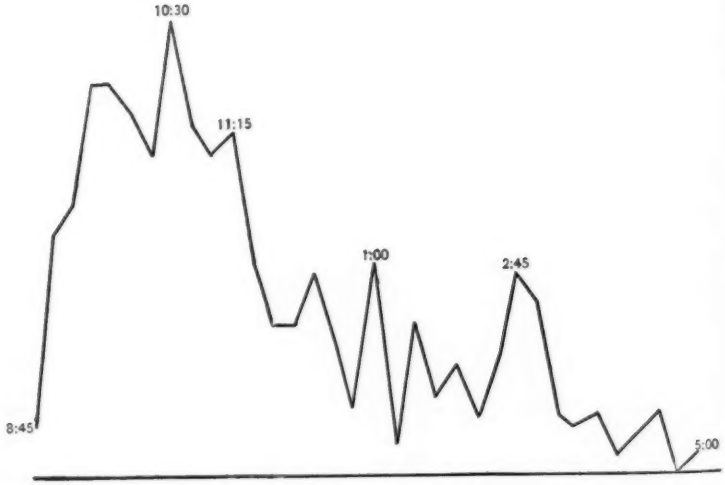


PLATE III.



Graphic Representation of Number of Birds Observed by 15-Minute Periods.

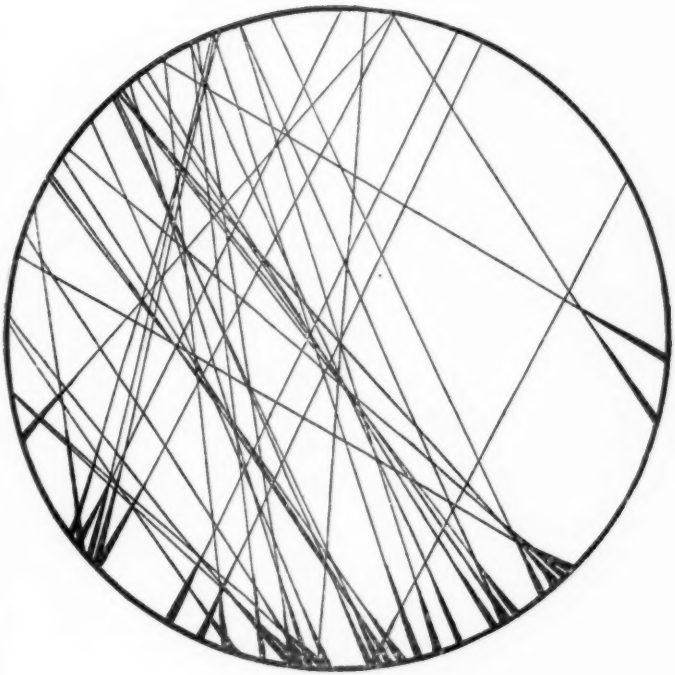


PLATE IV, No. 1.
August, 1898.

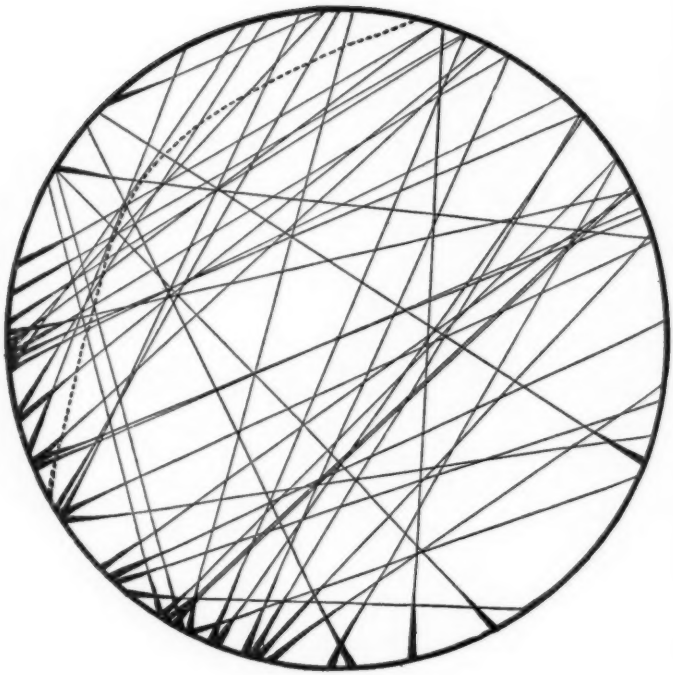


PLATE IV, No. 2.
September, 1899.

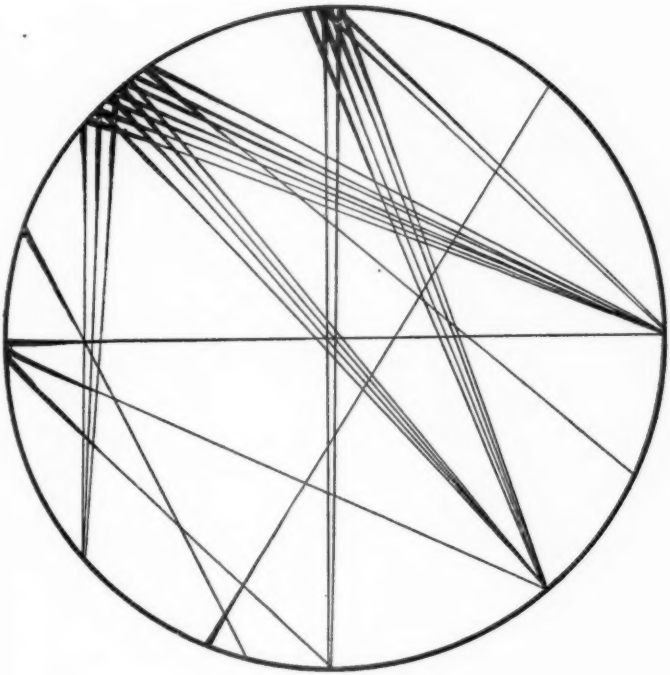


PLATE IV, NO. 3.
April, 1899.

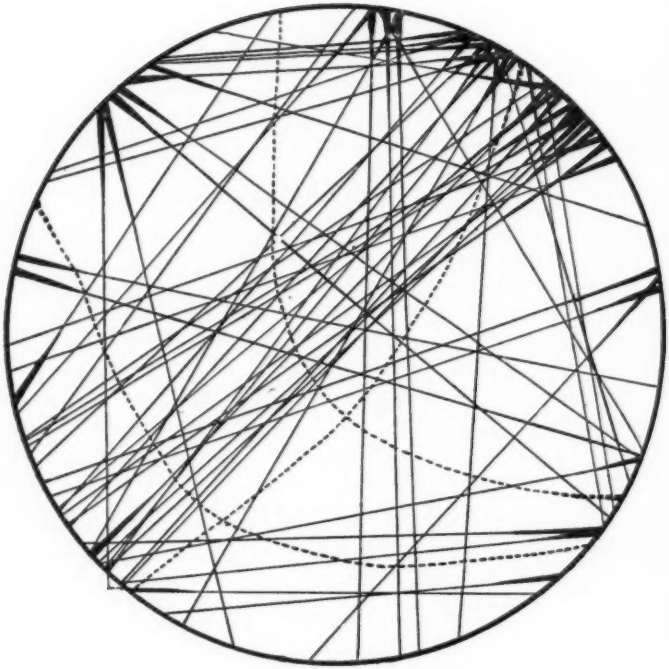


PLATE IV, No. 4.
May, 1899.

MINOR INVESTIGATIONS IN SENSE PERCEPTION.

By Robert MacDougall, New York University.

I. On Determinations of the Subjective Horizon by Motor Co-ordination.

In the first volume of Harvard Psychological Studies which has recently appeared (Monograph Supplement 17, Psychological Review), an investigation concerning the subjective determination of the primary point of regard is reported by the present writer. In connection with that series of experiments an examination was made of manual and oculomotor co-ordination in such processes of spatial orientation. The relation of these factors in certain phenomena is well known. If the lateral axis of the head or the primary sighting-line of the eyes be not horizontal, the relations of the fundamental planes of space will be subject to distortion when these are determined by motor co-ordination of the hands. More specifically, if the head be tipped backward or forward, to one side or the other, the determination of horizontal lines in the plane of displacement will be negatively rotated. When the head is tipped toward the right, if one attempt to hold a bar in the two hands horizontally before the body and parallel with its lateral axis, the left end will unconsciously be depressed; if the tipping be toward the left, the right end of the bar will be depressed. These results are independent of the relation of the horizontal plane in which the line in question lies to that of the observer's eyes.

The problem to be determined in the experiments reported in the Harvard Psychological Studies concerned the factors of visual space orientation of this form under normal conditions, and the influence of unusual strains, positions of the body, and relations of external objects upon such determinations. Judgment was found to be affected by all of these, the movements and tensions of the eye-balls having the greatest influence. In connection with this investigation it became of interest to ascertain the relation of the subjective horizon of the eyes as determined by raising the index finger, to its position when determined visually, and the influence upon such location of changes in the orientation of the head and eyes.

The experimental arrangements of the previous investigation were maintained. Determinations of the horizon plane were made by the right index-finger in frontal and lateral vertical planes, the eyes being closed during the experiments, and the arm brought to a resting position in the lap between successive trials. The following experimental variations were to be tested. For determinations in both frontal and lateral planes, the position of the head being normal (a) locations with the eyes in their primary position; (b) locations with the line of sight elevated to the limit of unstrained adjustment; (c) locations with the line of sight similarly depressed. For determinations in the frontal plane alone—(a) locations with the head tipped upward and back; (b) locations with the head tipped forward and down. For determinations in the lateral plane alone:—(a) locations with the head tipped toward the right; (b) locations with the head tipped toward the left. Ten observers took part in the experiment. The individual averages of these were based upon series of fifty judgments each. The magnitudes of the angles of elevation and depression are given in degrees and fractions.

The results may be briefly summed. The plane of the subjective horizon under normal relations of body position is negatively rotated through a much greater angle than in visual determinations. The downward displacement increases from $-7'.70$ in locations made by the eye in a lighted room to $-48'.9$ in those made by manual co-ordination. It was found in the previous investigation that when the determination of the subjective horizon was made with closed eyes the line of sight was elevated to a point above the gravity horizon, the characteristic error being $+ 23'.69$. The discrepancy between eye and hand is therefore to be reckoned thus much greater than the value of the absolute displacement, ($48'.90 + 23'.69$, or $- 72'.59$). The reason for this large error is to be sought in the normal co-ordination of these organs in the indication of positions in space. In pointing to any object the index-finger is habitually directed to a point below its actual location, in order that the line of vision may be left unobstructed. The free determination of the subjective horizon has thus reinstated the ordinary relations of eye and hand involved in simultaneous looking and pointing toward objects in that plane, and the characteristic error of location is therefore due finally to the anatomical relations of these two bodily members.

Determinations made with the line of sight of the closed eyes elevated (Experimental variation, I, b).) are marked by a negative displacement of large magnitude, the location now being,— $204'.40$. The depression of the line of sight, on the other hand; (Exper. var., I, c).) is followed by no appre-

ciable displacement, the absolute location of the horizon, namely,— 49′.90, practically coinciding with that made under normal relations of the head. The difference in the results of these two forms of head rotation indicates apparently the significance of sensations of eye-movement and strain upon the process of localization. The degree of rotation in a bodily member is judged by the sensations of strain which develop in the course of its translation. As the curve of intensity in such experiences of strain exhibits a progressive acceleration with successive increments of angular movement, there arises the possibility of illusions of position and errors of estimation. In the present case the upward rotation of the eyes in their sockets develops a relatively intense strain experience, while in rotations of equal magnitude downward from the primary position of the eyes these muscular tensions are practically lacking. This difference arises from the biological relations of the organism to its environment, which call forth constant exploring movements of the eyes within the lower half of the field of vision, while very few are made above the horizon in the expanse of the sky. As a result of this discrepancy in the increment of strain, the over-estimation of the amount of rotation and consequent exaggeration of the corrective adjustment which appear in the one case are wholly absent in the other.

Results attributable to the same biological conditions appear when the whole head is rotated upward or downward. Upon the former movement follows a negative displacement of— 146′.50; upon the latter, a displacement of — 239′.40. When the chin is tilted upward, as was pointed out in the previous investigation, a reflex negative rotation of the line of sight takes place, which is practically lacking when the chin is dropped; the eyes move with the head in the latter case, while in the former they move independently of it and in the opposite direction. This downward rotation of the eyes does not involve noticeable sensations of strain; there exist, therefore, only the positive tensions of the supporting muscles of the head as factors of possible error in the first case, the effects of which appear in the negative displacement of the imaginary horizon. When the chin is depressed both systems of strain are reduced and there appears therefore a return to the normal co-ordination of hand and eye with a resultant large depression of the manually determined horizon, dependent upon the depression of the line of sight.

In all these cases the variability of the judgment is greatly increased over that of visual determination, the values of the mean variation being for rotations of the eyes:—normal, 55′.37; upward, 58′.80; downward, 56′.2; and for the head:— upward, 79′.80; downward, 60′.10. Every abnormality of

position also reduces the accuracy with which the judgment is reproduced. Of the two forms of bodily displacement compared in the present investigation the upward rotation of both eyes and head is marked by greater interference with the normal processes of judgment than movements in the opposite direction. This relation appeared also in visual determination of the horizon, and is to be looked for as a consequence of the different parts which these two forms of movement play in ordinary perception.

The attempt to bring the index finger to the level of the eyes and at arm's length from the side of the body results in the location of a point far below their true position, namely,— 332′.80. Both negative and positive displacements of the line of sight in the closed eyes during the process of locating these points in the supposed horizontal plane of the eyes are followed by characteristic errors, a phenomenon which does not appear in the results of experiments on the determination of objective planes under like circumstances. Rotation of the head in its frontal or lateral plane does not affect the process of adjusting horizontally a bar which intersects that plane at right angles. In the present instance the upward rotation of the eyes gives a displacement of — 380′.1, or — 47′.3 from the normal; their downward rotation gives a displacement of — 300′.8, or + 32.0 from the normal. The direction of the error in both these cases is identical with the negative rotation of the subjective horizon which has been observed by other investigators to take place when the head is tipped in line with the points determined in that plane. As in the preceding experiments the greater correction accompanies upward, the less downward, rotation. The very large negative error which appears in these latter determinations is the result of the higher degree of muscular strain involved in bringing the arm up to the horizontal plane of the eyes at the side of the body as compared with frontal movements, and is not to be referred to any of the factors which are of interest in the present discussion. This error was not at all suspected by the reactors, and to the unforced character of the movements, with probably the additional factor of practice, is to be attributed the low index of variability which this series presents. The values are as follows:—normal, 46′.7; upward rotation, 53′.9; downward rotation, 49′.1. As before, the mean variation is greater in the case of upward than in that of downward rotation.

The last group of experiments, in which the head was rotated laterally, was not completed, and the results cannot therefore be given quantitatively. Enough was seen, however, of the influence of these experimental variations to show that their effects were to produce the characteristic errors of

location which appear when the attempt is made to hold a bar in a horizontal position under similar abnormal bodily positions.

The conclusions to which these experiments lead may be summed up briefly. These forms of spatial orientation are related to oculo-motor conditions, and the direction of the characteristic errors which they present are dependent upon the co-ordination of eye and hand in the perception reactions of ordinary practical life. The variations in amount of this constant error are related to simultaneous changes of direction and amount occurring in the tension of the oculo-motor mechanism, specific errors regularly taking the form of displacements of a sign negative to the direction of rotation in the eye-ball. The variability of the process of determination is a function of the intensity of strain which characterizes the primary movements of the head and eyes, and is therefore dependent upon the degree of interference with normal conditions of functioning which the latter involve. The characteristic errors appear to depend upon the objective displacement of the point of regard, interpreted on the basis of the organic strains involved in the various types of rotation, rather than upon the internal relations of these displacements to the principal planes of the body. since the location of the subjective horizon is equally affected by rotations in either of two planes at right angles to each other. With these determinants combine certain constant factors of resident strain in the organ, to give specific form to the judgment, but the consideration of these elements does not belong to the present discussion.

II. The Relation of Saturation in Homogeneous Colors to the Area over which the Color is Spread.

The apparent intensity of a stimulus, it has been noted in the case of various sensations, depends upon the magnitude of the area to which it is applied. When the whole hand is plunged into warm water, for instance, it feels hotter than when only the tip of the finger is immersed. If the taste of a substance in solution be too weak to produce any sensation of taste when only a small portion of the tongue is stimulated, its flavor may become clearly discriminable when a larger quantity is taken into the mouth. This reinforcement of the intensity of sensation by increasing the number of sensitive elements affected becomes our common practical method in the discrimination of faint odors.

It is a natural inference from the connection which is found in these instances that the number of elements of the sensitive surface stimulated and the intensity of the resulting sensation stand always in such a relation of functional dependence that

the subjective estimation of the intensity of a sensorial stimulus cannot be considered apart from the magnitude of the area excited.

In the case of certain senses it has been noted further that this summation effect is independent of continuity in the surface to which the stimulus is applied; intensive reinforcement takes place when the sensitive elements affected are not contiguous but form a discrete series. Thus in color vision if homogeneous light be distributed in the form of isolated spots of color the presentation of a sufficient group of these will give rise to a perception of their characteristic quality though the area of each individual unit be below the threshold of discriminability.

The small experiments reported in this paper concern two points in this general field; first, the quantitative relation of intensity to the number of elements stimulated in visual sensations arising from stimuli spread over continuous extents; and second, the quantitative relation of the stimulation area to the color threshold in continuous and discrete extents.

In studying the relation of saturation or color intensity to the area over which the color is spread three areas were compared, a unit of one square centimeter and two variables of four and sixteen square centimeters respectively. The series of six so-called pure saturated colors of the Bradley papers was employed. A double spindled color mixer was used, upon one shaft of which was mounted an unbroken disc of color, while upon that adjacent to it was mounted a combination of discs, including black and white as well as the color to be observed. In front of the revolving discs and just clear of their surfaces was stretched a screen of neutral gray paper, in which, near by each other, were cut two apertures having the areas of the unit and of the variable to be compared with it, respectively. Experiments were performed in indirect sunlight, the illumination coming from a point directly in front of the screen. The observer sat at a distance of one metre from the disc. Determination was made by immediate comparison of the saturation of the adjacent color areas, the record being made in terms of the angular magnitude of the color sector in the variable area, that of the unit being in all cases 360°. The work was obviously slow, since it was necessary to adjust the relative amounts of white and black in the neutral light introduced as well as the proportion of colored and uncolored light, in order that uniform brightnesses might be maintained between unit and variable areas. Two observers took part in the experiment; as the results in the two cases were parallel, only their averages will be given.

The proportions of colored light for each of the color qualities involved for the several areas are as follows:

	1 sq. c.	4 sq. c.	16 sq. c.
Red,–	360	342	318
Orange,–	"	295	270
Yellow,–	"	320	271
Green,–	"	282	261
Blue,–	"	341	324
Violet,–	"	298	240

The functional relation of the two factors appears in each of the two progressive variations introduced, and is exhibited by all members of the group of colors tested. In order to equalize the apparent saturation of two differing color-areas that of the larger must be reduced by the addition of a greater or less amount of uncolored light, varying according to quality and to the difference in magnitude of the areas. With progressive increase in the area of the colored surface the degree of apparent saturation likewise mounts. To what range of extents this relation applies, the present experiments do not show, since the greatest area included was still relatively small. The facts point toward the inclusion of all areas up to the limits of the total field of vision as thus affecting by their magnitude the saturation which the color presents; in other words a visual field all red or green is more vividly red or green than is any portion of that field seen amid neutral surroundings.

Since in the opposite direction the reduction of the retinal area stimulated, when carried to a certain point, results in the total disappearance of the color impression, we may say that the intensity of the latter is related throughout all its degrees to the area over which the stimulus is spread. It is not seen at its full intensity as soon as it is seen at all, but parallel with the enlargement of its area presents a series of intensive increments which at first are very rapid as the color area extends beyond the threshold, and afterward very slow; so that a spot of color just clearly discernible is scarcely less intense than the larger areas to which our ordinary experience is limited. The intensity of the color element in a given visual extent, however, is always less than that of any greater area having the same objective constitution, so that we should call only that color field fully saturated which extends to the whole field of vision.

The value of the differential factor of neutral light increases in the following color order: Red, Blue, Yellow, Violet, Orange, Green; in other words there is least difference in saturation between small and large areas of red, of all the colors observed, and most difference in the case of green. Therefore

the influence of the number of elements stimulated upon the intensity of the color sensation is greatest in the case of green, least in that of red. It will be recalled that in respect to energy these two colors form the opposite terms of the series (according to Langley's determinations), green possessing the greatest and crimson the least energy.

To the preceding series of experiments was added a set of observations on the relation of brightness intensities in neutral light when distributed over different areas. The phenomenon presented here is not the same as in the case of color, since in comparing neutral brightnesses the background is homogeneous in quality with the areas to be observed, in so far as it must possess the element of brightness. The so-called brightness is therefore virtually contrast with the gray background against which the area in question appears, and in reading the results one must estimate the various quantities as degrees of divergence in either direction from this zero-point.

The screen employed was that used in the preceding set of experiments; it corresponded approximately to a gray produced by the combination of black and white in the proportions, 270°, and 90°. In the series of brightnesses descending from this positive degree of illumination only one point was determined, while three were tested in the series ascending toward white, giving five combinations, having the following amounts of white in angular magnitudes: 0°, 90°, 180°, 270°, 360°. The proportions which gave equivalent subjective brightnesses for the three experimental areas are as follows:

1 sq. cm.	4″	16″		
0.0°	5.5°	9.7°	deg.	white.
90.0°	102.5°	90.0°	"	"
180.0°	189.5°	171.5°	"	"
270.0°	250.5°	241.5°	"	"
360.0°	315.0°	296.5°	"	"

In the first combination of the series the relations to be predicted are found to hold. The illumination of the experimental area in this case is less than that of the screen and its surface appears dark in contrast with the lighter gray background. The degree of this contrast increases with each increment of area; in other words, the darkness of the larger surface appears more intense both in the relation of the smaller variable to the unit and in that of the larger variable to the smaller. In the second combination of slightly weaker illumination than the background, and the third which was next above it, no definite direction of change is manifested, as might be expected. In the fourth and fifth of the group,—in both of which the illumination of the experimental areas was

distinctly greater than that of the background,—the dependence of contrast intensity upon area again appears definitely. It is to be observed that this influence increases in degree as the absolute difference between foreground and background grows greater. The amounts of black introduced in the several combinations give the following series of percentual values for the first and second variable areas respectively:

W 180	W 290	W 360	Area.
5.0 %	7.4 %	12.5 %	4 sq. em.
	10.7 "	17.7 "	16 " "

The figures present an approximation to the relations formulated in Weber's law, but it is questionable if a more extended series would continue the curve.

III. The Quantitative Relations of Stimulation Area and Color Threshold in Discrete as Compared with Continuous Extents.

In connection with a series of experiments upon the quantitative values of the color thresholds of homogeneous light, and of the visibility of such light qualities against colored backgrounds, it became important to compare quantitatively the color threshold depending upon a continuous extent of color with that arising from the distribution of the color in isolated spots over a larger field. It is the latter point only which is to be reported here.

The colors used and the conditions of lighting were as in the preceding experiments. Thresholds were tested for four colors only: red, blue, yellow and green; but to avoid inferential judgments some twelve qualities in all were used. The stimulation areas were controlled by means of sliding screens of dull, black-faced paper, so arranged as to present always a square. The observer sat a distance of six meters. The results are given in terms of square millimeters, and represent the average of five determinations. Two observers took part in the experiments.

The square area was first divided into two equal parts by a diagonal band of black, made successively two, five, and ten millimeters in width. With this arrangement determinations of red only for one observer, and of red and green for the other, were made. The results follow:

Obs.	Solid	2 mill.	5 mill.	10 mill.	
A.	48	35	30	15	Red.
B.	[1]160	116	120	78	Red.
	90	72	69	16	Green.

[1]The relations of absolute magnitude in the two observers, or in different colors, have no significance, since the determinations were made by daylight and only single series could be made under conditions of approximately constant illumination.

The area was next divided into four equal sub-areas by two diagonals having successively the widths of two, five and ten millimeters as before, with the following results:

Obs.	Solid	2 mill.	5 mill.	10 mill.	
A.	48	48	40	25	Red.
B.	160	145	99	40	Red.
	90	65	64	42	Green.

The stimulus was then distributed in the form of circular areas two millimeters in diameter, which were arranged in vertical and horizontal rows separated by successive distances of two, five and fifteen millimeters, with the following results:

Obs.	Solid	2 mill.	5 mill.	15 mill.	
A.	48	43	28	25	Red.
	94	18	15	12	Green.
B.	160	39	48	31	Red.
	90	25	37	28	Green.

Two other modes of distributing the stimulation-area were added to those already described, but as the results in each case were analogous to the preceding, they need not be repeated. The determinations of the thresholds for solid extents were made some weeks earlier than the rest of the results quoted. This may account for the great reduction of the threshold for red in B's results. Figures for blue and yellow are not given. Yellow could be discriminated (from white) only when a larger area was presented than could conveniently be arranged for with the apparatus used. The determinations of the thresholds for blue were very variable and unreliable on account of a similar constant confusion with black.

The quantitative relations presented by the tables may be stated in a word, since the same essential curve is exhibited by all. The maximum value of the threshold is reached when the color forms a solid extent. Its minimum value, within the range of conditions included in the present observations, is found when the area is sub-divided and its parts are most widely distributed over the retina. Between these two limits the value of the threshold increases and decreases as the constituent areas approach aggregation or depart from it. It appears then that color is most readily perceived not when it forms one continuous field but when it is distributed as separate patches within a larger area. An extent which is far below the limits of visibility under the former conditions may become clearly discriminable when it forms a group of smaller color spots. The influence of magnitude in the constituent areas is not so clearly shown as is the factor of separation among these parts.

If we abstract from the fact of local variations in the sensitiveness of the retina to color stimulation we should interpret the present results as indicating that any effect of reinforcement which the stimulation of individual points of the retina has upon the total effect produced is greater when these points are separated by unstimulated elements. If the important factor in such cases is the number of sensitive elements stimulated, and not the intensity of excitement aroused, the condition of distribution presents more favorable relations for perception than aggregation. The positive stimulation of any restricted portion of the retina affects also the adjacent unstimulated parts. The total irradiation effect thus produced must depend upon the proportion of stimulated points which are adjacent to elements not directly stimulated. This reaches its minimal value when the points immediately excited form a continuous extent. It would theoretically attain its maximum when each physiological unit was in isolation, but the practical limit may depend upon the co-operation of a variety of factors. This is sufficient to explain the results here presented.

It is possible that the phenomenon is due to an entirely different cause, namely the curve of color sensitiveness presented by a radial series of retinal points. The lowering of the threshold which follows upon dispersion of the stimulated points would then be dependent upon the increased sensitiveness of the elements stimulated under these conditions over that of the foveal area affected when the color formed a continuous extent. A definite curve for the color blue would have important bearing upon this point; but, as has already been stated, this set of tests was too variable to be depended upon.

NOTE. The observations collated in these two reports were made by Messrs. Bacon and Johnson, Davison and Phipps.

AN INVESTIGATION OF FECHNER'S COLORS.[1]

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I. STATEMENT OF PROBLEM.

If a disc composed of black and white sectors is rotated with a moderate degree of rapidity, colors appear upon the anterior and posterior edges of the sectors. In other words, when excitation by black and excitation by white precede or follow each other at certain distances, whether these distances are determined by width of sector or by rate of rotation, there does not result a gray, as one might suppose, but color. The name of *Fechner's Colors* was first applied by Brücke[2] to the colors

[1] [The author of this paper was, unfortunately, seized with illness at the conclusion of her experimental work, so that she has been unable to give the article its intended form. Chs. I–IV have received some revision; ch. V is little more than a rough draft of the discussion as originally planned. Since the author cannot return to the work in the near future, I have thought it best to publish her MS. as it stands. —E. B. T.]

[2] Brücke, Ernst: Wiener Akad. Berichte, XLIX, 1864, 21-24.

produced by rapid alternation of black and white, in honor of the discoverer of the phenomena.[1]

The colors frequently appear under conditions not standardized; *e. g.*, if we glance up suddenly, we see colored borders on the window-frame; the edges of the leaves of our book are colored while we are in the act of turning them; or the edges of the printed line are colored as our eyes move rapidly up or down the page. That is, one of the essential conditions upon which the production of the colors depends is movement; color appears when there is not perfect accommodation of the eyes.[2] But under standard conditions, when the sectors of the disc are equal and of definite size, when the rate of rotation is regulated, and when the degree of illumination is kept constant, certain colors will appear in certain places, and with variation of one or more of the conditions the colors will also vary *in a definite direction*.

Since 1838 many means have been devised for the production of the colors. The most convenient way of obtaining alternation of black and white is to use a pasteboard disc composed of sectors of different sizes. The disc can easily be rotated, and its speed can easily be regulated,—both by means of apparatus which can be kept constant through long periods. It permits of many variations in division of sectors as regards size and position. Papers of different colors or brightnesses may be put on it, or sectors of the disc may be cut out.

The difficulty, indeed, has not been to find ways of obtaining the colors, but to find the explanation for them. More than half a century has elapsed since Fechner made his experiments, and during this time scores of articles concerning intermittent stimulation of the retina have been published; but as regards the cause we may even now agree with Fechner and Brücke that we know more at the beginning than we know at the end of our investigations.[3] This result is, of course, due to our general ignorance of the exact processes which take place in the retina during and after stimulation. Experiments have been made to show that the periods of rise and fall are

[1] An article by Sir David Brewster, in the Philos. Mag., N. S. IV, 1834, describes some effects of rapid changes of retinal stimulation. This is probably the one discussion in scientific literature which might be considered a previous description of the facts noted by Fechner. But Brewster's article could with little justice be said to record the discovery of the phenomena in question, for the explanations are different, not to our point; and both discs and experiments were made with a different end in view.

[2] The instance in question is not similar to that of von Bezold's rings, dependent upon fixation. Helmholtz, Phys. Op., 2nd Ed., 156.

[3] Brücke, Ernst: Pogg. Ann., LXXXIV (whole ser. CLX), 1851, 418.

different for different colors.[1] In another way, retinal inertia is shown by means of rapid alternation of stimulation.

II. Literature.

As early as 1838, there appeared an article by G. T. Fechner, *Ueber eine Scheibe zur Erzeugung subjectiver Farben*, in which he describes the disc by means of which he first produced these subjective colors.[2] The fact that Fechner discovered the phenomenon quite accidentally does not lessen its interest for us, since the description of the observations is given very fully. Fechner had prepared a disc with 18 concentric rings for the production of different shades of gray; but upon its rotation he was astonished to see a series of colors. They were not of great intensity, yet were not without a certain vivacity. He found that the colors were perceived by different persons with unequal clearness,—a fact which, in view of their subjective nature, was not considered at all surprising. The reason for the result he found in the fact that the effect made by white light does not die out with equal rapidity for all rays of which it is composed.

Much later than the appearance of the article by Fechner, Helmholtz describes the production of a "flight of colors" by means of a black and white disc.[3] When a part of the retina is exposed to rapid alternations of white light and of darkness, causing successive states of increasing and decreasing excitation, the moment of maximal excitation is not the same for all colors.

Helmholtz made use of two sorts of discs: the one consisting of a black spiral line on a white ground; the other a disc half black and half white, whose sectors were divided to form three concentric rings, the center ring divided so that its sectors formed halves, the second fourths, the outer eighths. Upon rotation, red appeared upon the anterior border of white, blue upon the posterior border. With decrease of illumination the red became orange, the blue violet. With increase, the red became rose, the blue a greenish-blue. With increase in rate of rotation, the colors passed through rose-violet to green-gray, and finally assumed an appearance similar to that of watered silk. These phenomena did not appear immediately, but only after practice, and a certain state of fatigue seemed necessary for their production. From these facts Helmholtz derived the conclusion that the moment of maximal excitation varies with the color, coming for red and violet sooner than for green.

[1] Kunkel: Arch. f. d. ges. Physiol., IX, 1874, 197.
[2] Pogg. Ann., XLV, 1838 (whole ser. CXXI), 227-232.
[3] Phys. Op., Ed. 1, 1867, 380; 2nd Ed., 1896, 530.

Aubert[1] verified the results obtained by Fechner almost as soon as they were published, and in addition noted the importance of one of the conditions necessary for the production of these colors, namely, the velocity. Extensive and accurate experiments were made to determine the exact rate which gave the most luminous colors. Aubert's general result is that too rapid or too slow rotation of the discs produces no color. These results will be discussed later in more detail.

Dove[2] does little more than report the results obtained by Fechner, although his work upon subjective colors produced by other means makes valuable additions to psychological optics.

J. Smith[3] describes the production of very brilliant luminous colors by means of rings of white or black. This is all that is of value for us; the author himself expresses the belief that the production of colors by such means overturns all accepted theories of light. He believes the experiments to be original.

Rood,[4] like Dove (pp. 171-7), obtained only lustre by alternating rather large masses of black and white. No colors are described.[5]

In 1881 a preliminary report upon the problem was made by F. J. Smith.[6] He used an ordinary wheel in making his experiments, and reports that there is an apparent relationship between spoke-interruption and wave length. Hannay experimented with a black and white disc, and came to the conclusion that response to stimulation is quickest for red; then follow green and blue[7]. He thinks that a passive observation adds to the brilliancy of the colors. This article was criticised by Napier Smith, who asked how the explanation given by Hannay accounted for the fact that black and white mixtures produce different colors, and why a certain movement should give red and the reversal blue.[8] If, however, Smith understood his discs, he would not find occasion for surprise in the fact that reversal gives a different color. To reverse the disc means to reverse the conditions. There would rather be reason for surprise if the phenomena remained constant while the conditions varied.

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[1]Aubet, H.: Physiologie der Netzhaut, 1865, § 161, 377-380. Less detail in Græfe's Hd. bh. der Augenheilkunde, II, 1876, 560. Also referred to as the Grundzüge der physiologischen Optik.

[2]Dove, H. W.: Farbenlehre, 1853, 281-283.

[3]Smith, John: Reports of Brit. Asso., XXIX, 1859, 22.

[4]Rood, O. N.: Am. Jour. Sc. (Sillman's Jour.), Ser. II, XXXV, 1865, 375.

[5][*Cf.*, however, Rood's Modern Chromatics, 1879, 93 ff.; Text-book of Color, 1881, 93 ff.]

[6]Smith, F. J.: Nature, XXIV, 1881, 140.

[7]Hannay, J. B.: Nature, XXV, Apr. 1882, 604.

[8]Smith, Napier: Nature, XXVI, May 1882, 30.

No strenuous efforts were made to solve the problem of these subjective colors for several years, until 1894, when there appeared a disc made by Benham upon a plan somewhat different from those used heretofore, which brought out the colors with astonishing clearness. The phenomena of the disc were for a few years vigorously discussed in English and American scientific literature.

The fact either that the new discs were made upon a plan widely differing from that of the old discs, or that the colors were greatly intensified by the use of fine lines rather than of large blocks of black and white, so disguised the old phenomena that they were not recognized. The greater part of the later investigations are reported as if they concerned entirely new phenomena. The 'top' appealed to many as a new problem calling for solution. The new disc, or top, is one half black, the other half white. The white half is divided into three sectors of 60° each, or four of 45° each; each angle is subtended by groups of arcs, whose radii increases arithmetically from center to circumference. This arrangement produces colors which vary from distinctly brilliant and luminous qualities to shades and tints which are disputable as regards both name and mere existence. The layman who is asked to describe a certain disc will often name the colors as accurately and unhesitatingly as the scientific observer who is more or less prejudiced by expectation.

Soon after the appearance of the disc, which has been given the name of the *artificial spectrum top*, many explanations of the phenomena were offered. One of the first attempts at explanation was made by G. D. Liveing, who exhibited the top before the Philosophical Society of Cambridge.[1] He observed that if *black* is *followed by white* at not too great rapidity a sensation of red results; if *white* is *followed by black* a sensation of blue is aroused; if black and white follow each other rapidly, drab or a neutral green is seen. These are practically the results obtained under similar conditions by all observers.

Regarding the fact there is no dispute; regarding the explanation there is scarcely any agreement. Liveing's explanation called forth almost immediately criticisms or alternative explanations from Abney,[2] Finnigan and Moore,[3] Benham,[4] and Bidwell,[5] besides notes calling attention to modifications in the preparation of the disc.

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[1]Liveing, G.D.: Cambridge Phil. Proc., Nov. 26, 1894. Also Nature, LI, Dec. 13, 1894, 167; LI, Dec. 27, 1894, 200.

[2]Abney, Capt. W. deW.: Nature, LI, Jan. 24, 1895, 292.

[3]Finnigan, J. M., and Moore, B.: Nature, LI, Jan. 24, 1895, 292-3.

[4]Benham, C. E.: Nature, LI, Dec. 27, 1894, 200.

[5]Bidwell, Shelford: Proc. Roy. Soc. London, LX, 1896, 368-379.

Only the various explanations will be taken into account here. Strangely enough, it was not until after a long discussion that Edridge-Green called attention to the fact that none of the previous writers seemed to be aware that Helmholtz had explained the phenomena in detail.[1]

Liveing explains the phenomena by saying that the impression made upon the retina by a bright light remains for some time after the cause of it is removed, and that different colors are perceived with different rapidities. Red is perceived with the greatest rapidity; the impression of blue has the longest duration; the overlapping of these sensations produces the neutral tint, a sort of gray-green. No evidence for these facts, other than the phenomena in question, is given.

Abney thinks that the phenomena would be sufficiently accounted for if the order of persistence of the three colors were violet, green, and red.

Finnigan and Moore suggest as causes irradiation (although this seems to be ruled out by the fact that change in rate of rotation causes change in color), and contrast with the surrounding white field.

Bidwell made more extensive experiments than any other of the recent investigators, but made them mainly for the purpose of showing that the solution of the problem is to be sought in the fact of sudden changes in illumination. To say this, however, is merely to point out what the problem is. In the way of explanation, Bidwell comes to the conclusion that red is without doubt due to sympathetic excitation. Blue, he says, may be due to excitation of the nerve-fibres in the neighborhood of those excited by the direct action of light; or it may be due to the scattering of light by imperfectly transparent media. He prefers to suspend judgment with regard to blue. But at any rate, he declares, the experiments show that red originates in a part of the retina not exposed to light, blue in a part where light has not ceased to act.

Rivers gives a short historical account of the phenomena.[2] He is inclined to doubt the validity of the explanations offered by Helmholtz and Fechner and to accept Bidwell's theory, although, he says, the distinctness of the red in Bidwell's experiments is to be expected if this color reaches its maximum with the rapidity ascribed to it by Kunkel.[3]

Bowditch, also, scarcely more than notes the phenomenon:[4] "when the image of a white object is moved across the retina it will appear bordered by colored fringes, since the various con-

[1] Edridge-Green, F. W.: Nature, LI, Jan. 31, 1895, 321.
[2] Rivers, W. H. R.: Schæfer's Text-book of Physiol., II, 1900, 1074.
[3] Kunkel: Arch. f. d. ges. Physiol., IX, 1874, 197.
[4] Bowditch, H. P.: Am. Text-book of Physiol., 1896, 789.

stituents of white light do not produce their maximum effects at the same time;" . . . there would then appear "colors which vary with the rate of rotation and with the amount of exhaustion of the retina."

This review of the literature shows us that there are three well-marked periods during which the phenomena of Fechner's colors have been investigated, but that scarcely any advance has been made beyond the results obtained by the original investigators of the problem, except as regards the *preparation of the discs* for the production of the colors. The reports have been cursory, and no one has attempted a systematic explanation in terms of current theories of visual sensation.

III. Apparatus and Methods.

Work was carried on in the Cornell Laboratory from the fall of 1898 until the spring of 1891. The major part of the experiments were made in a dark room, for the purpose of securing an approximately constant and easily regulable light; during only a few experiments were the discs illuminated by diffuse daylight. The greater part of the experiments were performed during the morning hours.

The power by which the discs were rotated was obtained from a Crocker-Wheeler motor, whose speed was reduced by a Pillsbury speed reducer. From this a belt ran to a Zimmermann mechanical color-mixer, which was made to rotate at the rate of 4.3 rotations in the 1 sec. The rate was tested at the beginning of each experimental hour, and often during the hour, although a variation of one or two rotations from 130 in the half-minute did not cause any appreciable change in color quality.

The observers sat close to a large black screen which stood 55.2 cm. from the disc, and in which was an opening of 21 x 15.5 cm. Behind this screen, and 43 cm. from the disc, was a Welsbach gas-burner, which furnished the whitest steady light that could be found. The black screen was protected from the heat of the lamp by a white abestos screen, which acted further as a reflector.

The following lists describe the discs in such a way that duplicates may easily be made. (For the general appearance of the discs, *cf.* Fig. 1 of the plate; for variations of the conditions, *cf.* the list of discs.) The columns lettered A, B, C, D, designate the *sector* in which a certain ring is found. The sectors are lettered *from right to left.* The figures which follow the color named stand for the *ring* which will be made when the disc is set in motion; while the color-name itself stands for the quality which lines, drawn in the position designated, will give rise to after the disc has been set in motion. For the sake of

greater convenience, in order to designate the position of the ring we shall use the name of the *color* which will appear to the normal eye while the disc is being rotated. Thus we see that, while the position of the sectors must remain constant, the position of the rings may vary within certain limits. For example,—to anticipate a little,—red and blue lines must appear in either sectors 1 or 4, but may extend through 2 or 3; green and yellow must appear in sectors 2 or 3, but cannot extend entirely through 1 or 4 without destroying their peculiar conditions. On the other hand, the groups of arcs may be at any radial distance from the center, and still fulfill the conditions necessary for the production of a certain color. Unless express statement is made to the contrary, the discs are divided into either 3 or 4 sectors, with 3 or 4 rings. Each ring is usually made up of 4 lines 1 mm. wide, the lines 3 mm. apart, the groups 5 mm. apart, the first group 10 mm. from the center. The color-names in parentheses denote the colors of the background. (The 'primary' colors are those of Bradley's colored-paper series.)

	A.	B.	C.	D.
1.	Red, 1	Green, 2	Blue, 3	
2.	Red, 1	Green, 2	Blue, 3	
3. Divided into quarters.	Red, 1	Green, 2	Blue, 3	
4. 3 broad lines.	Red, 1	Green, 2	Yellow, 3	Blue, 4
5. 5 & 6 1 mm lines.	Red, 1	Green, 2	Yellow, 3	Blue, 4
6. 3 fine lines.	Red, 1	Green, 2	Yellow, 3	Blue, 4
7. 2 broad lines.	Red, 1	Green, 2	Yellow, 3	Blue, 4
8. 3 fine lines overlapping sectors.	Red, 1	Green, 2	Yellow, 3	Blue, 4
9.	Red, 4	Green, 3	Yellow, 2	Blue, 1
10.	Red, 1	Green, 2	Yellow, 4	Blue, 3
11.	Red, 3	Green, 2	Yellow, 1	Blue, 4
12.	Red, 3	Green, 1	Yellow, 4	Blue, 2
13. Short lines.		Green, 2, 4, 5	Yellow, 1, 3	
14.	Red, 1, 3,			Blue, 2, 4
15.		Green, 1, 2, 3, 4		
16.			Yellow, 1, 3, 4 Blue, 2	Blue, 2
17.	Red, 2, 4	Red, 2, 4 Green, 1, 3		
18.	Red, 4	Red, 4	Yellow, 1, 3 Blue, 2	Blue, 2
19.			Yellow, 1, 2, 3, 4	½ sector. Green, 1, 2, 3, 4
20. Last ½ sector.	Green, 4	Green, 4	Yellow, 1, 3 Blue, 2	½ sector. Green, 1, 3 Blue, 2

21.		Green, 1, 2, 3, 4	Green, 1, 2, 3, 4	
22. 1 cm. line.	Red, 1	Green, 2	Yellow, 3	Blue, 4
23.	Red, 1			
24.	Red, 1	Green, 2		Blue, 3
25.	Red, 1, 2, 4	Red, 2, 4 Green, 3	Red, 4	
26. Movable black sector.	Red, 1	Green, 2	Yellow, 3	Blue, 4
27. See Plate.				
28. $\frac{1}{12}$ black.	Red, 1	Green, 2	Yellow, 3	Blue, 4
29. $\frac{1}{8}$ black.	Red, 1	Green, 2	Yellow, 3	Blue, 4
30. $\frac{1}{4}$ black.	Red, 1	Green, 2	Yellow, 3	Blue, 4
31. $\frac{3}{8}$ black.	Red, 1	Green, 2	Yellow, 3	Blue, 4
32. $\frac{5}{8}$ black.	Red, 1	Green, 2	Yellow, 3	Blue, 4
33. $\frac{3}{4}$ black.	Red, 1	Green, 2	Yellow, 3	Blue, 4
34. $\frac{7}{8}$ black.	Red, 1	Green, 2	Yellow, 3	Blue, 4
35. Plate.	Red, 1	Green, 2	Yellow, 4	Blue, 3
36. Plate.	Red, 1	Green, 2	Yellow, 4	Blue, 3
37. Plate.	Red, 1	Green, 2	Yellow, 4	Blue, 3
38. Plate.	Red, 1	Green, 2	Yellow, 4	Blue, 3
Discs with colored back-grounds.				
I—1.	Red, 1 (red)	Green, 2 (red)	Blue, 3 (red)	
I—2.	Red, 1 (green)	Green, 2 (green)	Blue, 3 (green)	
I—3.	Red, 1 (blue)	Green, 2 (blue)	Blue, 3 (blue)	
I—4.	Red, 1 (yellow)	Green, 2 (yellow)	Yellow, 3 (yellow)	Blue, 4 (yellow)
II—1.	Red, 1	Green, 3	Blue, 2 (red)	
II—2.	Red, 1	Green, 2	Blue, 3 (green)	
II—3.	Red, 1	Green, 2	Blue, 3 (blue)	
II—4.	Red, 1	Green, 2	Blue, 3 (yellow)	
II—5.	Blue, 4	Yellow, 3	Green, 2	Red, 1 (yellow)
III—1.	Red, 1	Green, 2 (red)	Blue, 3	
III—2.	Red, 1	Green, 3 (green)	Blue, 2	
III—3.	Red, 1	Green, 2 (green)	Yellow, 3 (green)	Blue, 4
III—4.	Red, 1	Green, 2 (Blue)	Blue, 3	
III—5.	Red, 1	Green, 2 (blue)	Yellow, 3 (blue)	Blue, 4
III—6.	Red, 3	Green, 1 (yellow)	Blue, 2	
III—7.	Red, 4	Green, 3 (yellow)	Green, 2 (yellow)	Blue, 1
IV—1.	Red, 1 (red)	Green, 3	Blue, 2 (red)	
IV—2.	Red, 1 (red)	Green, 2	Yellow, 3	Blue, 4 (red)
IV—3.	Red, 1 (green)	Green, 3	Blue, 2 (green)	
IV—4.	Red, 1 (blue)	Green, 2	Blue, 3 (blue)	
IV—5.	Red, 1 (blue)	Green, 2	Yellow, 3	Blue, 4 (blue)
IV—6.	Red, 1 (yellow)	Green, 2	Yellow, 3	Blue, 4 (yellow)
V—1.	Red, 1	Green, 2 (red)	Blue, 3 (red)	
V—2.	Red, 1	Green, 2	Yellow, 3 (red)	Blue, 4 (red)
V—3.	Red, 3	Green, 1 (green)	Blue, 2 (green)	
V—4.	Red, 1	Green, 2	Yellow, 3 (green)	Blue, 4 (green)
V—5.	Red, 1	Green, 2 (blue)	Blue, 3 (blue)	
V—6.	Red, 1	Green, 2	Yellow, 3 (blue)	Blue, 4 (blue)
V—7.	Red, 1 (yellow)	Green, 2 (yellow)	Yellow, 3	Blue, 4
VI—1.	Red, 1 (red)	Green, 2 (red)	Blue, 3 (green)	
VI—2.	Red, 1 (red)	Green, 3 (red)	Blue, 2 (blue)	
VI—3.	Red, 1 (red)	Green, 2 (red)	Yellow, 3 (yellow)	Blue, 4 (yellow)
VII—1.	Red, 1 (green)	Green, 2 (green)	Blue, 3 (red)	
VII—2.	Red, 1 (green)	Green, 2 (green)	Blue, 3 (blue)	
VII—3.	Red, 1 (green)	Green, 2 (green)	Yellow, 3 (yellow)	Blue, 4 (yellow)

VIII—1.	Red, 1 (blue)	Green, 2 (blue)	Blue, 3 (red)	
VIII—2.	Red, 1 (blue)	Green, 2 (blue)	Blue, 3 (green)	
VIII—3.	Red, 1 (blue)	Green, 2 (blue)	Yellow, 3 (yellow)	Blue, 4 (yellow)
IX—1.	Red, 1 (red)	Green, 2 (green)	Blue, 3 (red)	
IX—2.	Red, 1 (red)	Green, 2 (blue)	Blue, 3 (red)	
IX—3.	Red, 4 (red)	Green, 3 (yellow)	Yellow, 2 (yellow)	Blue, 1 (red)
X—1.	Red, 1 (green)	Yellow, 3 (red)	Blue, 2 (green)	
X—2.	Red, 1 (green)	Green, 2 (blue)	Blue, 3 (green)	
X—3.	Red, 4 (green)	Green, 3 (yellow)	Yellow, 1 (yellow)	Blue, 2 (green)
XI—1.	Red, 1 (blue)	Green, 2 (red)	Blue, 3 (blue)	
XI—2.	Red, 1 (blue)	Green, 2 (green)	Blue, 3 (Blue)	
XI—3.	Red, 3 (blue)	Green, 2 (yellow)	Yellow, 4 (yellow)	Blue, 1 (blue)
XII—1.	Red, 1 (blue)	Green, 2 (green)	Blue, 3 (red)	
XII—2.	Red, 1 (blue)	Green, 2 (red)	Blue, 3 (green)	
XII—3.	Red, 1 (red)	Green, 2 (blue)	Blue, 3 (green)	
XII—4.	Red, 1 (blue)	Green, 2 (green)	Yellow, 3 (yellow)	Blue, 4 (red)
XIII—1.		Green, 4	Yellow, 3 (yellow)	
XIII—2.	Red, 4			Blue, 3 (red)
XIII—3.	Red, 3 (blue)			Blue, 4
XIII—4.	½ white, ⅜ black, ⅛ blue		Yellow, 4	Blue, 3
XIII—5.		Green, 2	Yellow, 4	(red)
XIII—6.	Red, 2 (yellow)			Blue, 3
XIII—7.	Red, 2 (green)	Green, 4.		

Thus there were in the entire series 97 top discs,[1] and one called the Helmholtz disc,[2] all 15.5 cm. in diameter. 38 discs were simply black and white, with the arcs and lines varying as regards length and width, varying also as regards the number of lines in each group and the disposition of the groups within the different sectors. The remaining 58 discs varied from the others by having a part or all of the white semicircle replaced by one or more colors. As regards distribution of colored back-grounds, the arrangement was as follows: I 1-4 all sectors of same color; II 1-5 sector 4 (or 3 and 4 according as there were 3 or 4 sectors on disc) colored; III 1-7 middle sectors or sector colored; IV 1-6 sectors 1 and 4 of same color; V 1-7 sectors 2 and 3 of same color; VI 1-3 to XI 1-3 all sectors colored, each disc having two sectors of one color and one (or two) of another,—part with the two like sectors preceding (or following) the third, and part with the two like sectors including the third. XII 1-4 had 3 or 4 sectors of different colors. XIII 1-7 were made up of odd combinations, with a single colored sector and with only two groups of lines.

[1] Part of the discs were made by Dr. J. E. Ives, now of the Univ. of Cincinnati, who began to study the problem at the Drexel Institute, Philadelphia.

[2] The figure given by Helmholtz, Phys. Op., 2nd ed. 195, Fig. 149.

The problems which arise with this arrangement of discs, besides the phenomena of colors, are (1) the effect of length of line upon the color, (2) the effect of width of line, (3) the effect of distribution of groups, (4) the effect of background color, (5) the effect of distribution and amount of background color. The last two are, obviously, problems of contrast effect. The part played by contrast was further investigated by cutting out (by use of a gray screen) all but one group of lines. The entire series was given once to each observer, who described the colors as fully and accurately as possible; this series was checked by a second, in which the colors were matched on the "Prang Standard of Color."[1]

Although useful as a check, this second series was not, on the whole, so valuable as the first. In the first place there were not on the chart enough combinations of saturation and brightness to match all the colors on the discs; this was especially noticeable with the "rich" navy blues. Here recourse was had to the Bradley colors; but even these were unsatisfactory. Further, the luminosity of the disc color was often greater than that of the chart, the chart color seeming by comparison to be "dead" or "dull." Changes in saturation degree from one plate of the chart to another were often more rapid than changes in the disc colors, so that the colors were said to be "between plates one and two," "two and three," etc. The matched colors were often supplemented by verbal reports.

Still, in spite of these difficulties, the reports may be said to be exceptionally accurate. This accuracy is vouched for by the fact that not seldom exactly the same chart color was chosen by two or more observers, though more often the same color tone was chosen, with a varying degree of saturation.

In the second series, the direction of rotation was changed, in order to prevent any expectation, and to bring out the effect of the position of the lines. As might be expected, this had no effect upon the color-tones, but merely changed their relative positions upon the dics, their brightness and their degree of saturation. In this series red appeared in sector D, green in sector C, yellow in sector B, and blue in sector A. The observer was frequently asked to rest, always, during the change from one disc to another, and, if the need was felt, during the observation of a single disc. On the average there were about eight discs studied during each experimental hour; at first less than this number, later more, the number varying with the observer and with the condition of the observer on different days. The observers were Mrs. I. M. Bentley (By.),

[1] Prang chart, Pop. Ed., No. 1, Pub. by Louis Prang, Boston, Copyright 1898.

Miss L. Hempstead (H.), Miss M. F. McClure (M.), Dr. C. R. Squire (S.), Dr. M. F. Washburn (W.), Dr. W. C. Bagley (B.), Dr. I. M. Bentley (Be.), and Mr. R. M. Ogden (O.) (For the earlier experiments in diffuse daylight the observers were Dr. G. N. Dolson, Dr. C. R. Squire, and Mr. C. A. Perry.) Besides these, there were many who looked at only two or three discs; this was for the purpose of testing the "layman," as regards perception of the colors without expectation or fatigue.

IV. Experiments and Results.

§ 1. Introduction.

The arrangements of black and white necessary for the production of the different colors are as follows. (1) Black *followed* immediately by white gives *red*. That is, there is a sensation of red at the first stage of excitation, brighter when the excitation is continued a *relatively* long time. The resulting sensation is made more vivid if there is co-excitation by black and white (*cf.* § 4, below).

(2) Black *both followed and preceded by* white gives rise to the sensation of *green*. *a*. If black is both followed and preceded by an *equal* number of degrees of white, the resulting color is *yellowish-green*. *b*. If black is *preceded* by *less* and *followed* by *more* white, the sensation is of a more saturated, more constant *green*. *c*. If black is *preceded* by *more* and *followed* by *less* white, the sensation is of a more yellowish, less constant green, called by us *yellow*.

(3) Black *preceded* by white gives rise to the sensation of *blue*. That is, there is a sensation of blue when the excitation by white has lasted for some time and is then suddenly cut off by excitation by black. The conditions for red and blue are distinguished by the position of the lines upon which the colors appear. Black is not cessation of stimulation, but a change in the character of the stimulation.

When the lines were so arranged as to fulfill the above conditions, the following reports were made:

Table 1.

Red was chosen	156	times out of	157	99%
Green "	189	" "	253	75%
Green or yellow "	159.5	" "	240.5	66%
Blue "	149	" "	164	91%

This general report necessarily leaves out of account the variations of tints and shades. These will be given with the more detailed reports.

Besides these differences, ascribed to individual peculiarities, there are also differences in color-quality caused by position (other factors remaining unchanged), by width and length of line. These problems will be discussed separately. The differences will be studied with each of the observers separately, so as to eliminate the indeterminable factor of natural individual differences; afterward, in order to determine the generality of any laws which may be found, the reports will be compared.

Before the special conditions are studied some of the more general conditions of observation may be noted.

§ 2. General Conditions. *a.* Attention.

It has been a question whether attention increases or decreases the brilliancy of the colors. This is a difficult question to answer. Perhaps it is best to answer it both affirmatively and negatively: affirmatively,—for we know that in general the effect of attention is to make the object of perception more clear and vivid; negatively,—because we know that attention fluctuates, and also because we know that the *fatigue* or *dissimilative* processes cause changes in the degree of saturation: there is light induction. We may say that attention aids in perception of color, that it clarifies the color, when not continued too long.[1] Red especially is brightened by being watched attentively. Attention seems to bring out the color when it is faint. (Be., S. and W., disc 25; B. and S., disc 27; By., discs 35-38). Closely connected with the question of attention is that of indirect vision. We saw that Hannay believes *passive* observation to be an aid in the perception of color. We can agree with him so far as to say that this is true occasionally,—but it is rather the exception than the rule. W. noted that, if she fixated beyond the disc, she could see all sorts of colors, rather mottled, covering the surface of the disc.

H. and O. noted that if they looked at the disc as a whole it had the appearance of being more generally covered with color than when they examined each separate ring. But the almost unanimous decision throughout the work was that *short periods of keen attention* aided in the perception of the colors.

b. Fatigue.

Looking "attentively" deadens the color, if the gaze is continued too long. "Too long" depends, to begin with, upon the saturation of the color. If it is merely liminal, the color will disappear almost immediately (H., disc 6, ring 3; S. 29, ring

[1]Aubert: Phys. der Netzhaut, 1865, 162, says in discussion of this point that if the ring itself be fixated it is gray, while the proximate place is blue.

4), or will change so that it cannot be matched (W. 1, ring 2; M. 9, 3 varied from III yyg 4 to B v; O. reverse of 10, 2). Very often the effect of fatigue is to make different lines of the same group appear in different colors; this was especially true of B., who scarcely ever showed general fatigue, but who showed it in this way more than the other observers. This change within the group, besides being due to fatigue, was also brought about by accidental variation of the lines. H. was especially sensitive to fatigue.

The Helmholtz disc, with its larger alternating masses of black and white, was more fatiguing than the finer alternating lines of the top disc. The disc was rotated 4.3 times in the 1 sec., at the same rate as the top discs. B., W., and O. reported on this disc, and all three reports were practically alike. Ring 1 was plainly divided into two sectors; the white was clearly tinged with yellow, and for W. had some red. Ring 2 for B. scintillated like mother of pearl, was yellowish with blue over it; for O., was blue and yellow, the yellow rather greenish,—the colors did not fuse but came in "daubs;" for W., the ring alternated yellow and violet-blue quite vividly. Ring 3 for all showed a great deal of yellow at the outer edge, as did the border of most of the other discs; for B. there was more yellow than in ring 2, and it grew yellower with gazing; there were flashes of blue-green very light and bright with dark shadows at intervals; for O., green and perhaps red were evident, but it looked as if there might be all colors 'if he could only pick them out;' for W., there were red and green, the latter a blue-green and quite bright; there was also a great deal of yellow at the edge. W. said immediately that the colors were fatigue effects, and noted this fact first in the increasing brightness of the whole disc, which disappeared after a rest. For both W. and O. all colors were gone from rings 1 and 2 after a rest; ring 3 "shimmered." For B. the colors came as rapidly as for the top discs.

c. Practice.

We must dissent from Helmholtz' assertion that practice is necessary for the perception of the colors, as well as from the statement that fatigue is necessary.[1] There were both laymen and experienced observers to whom the colors were so brilliant at first glance as to cause exclamations of surprise. But in this connection individual differences appear. To those for whom the colors were brilliant at first, they were always brilliant. To those who had difficulty in noting color at all, the colors were always dull (there were none of these among the regular ob-

[1] *Op. cit.*, 530, Fr. 502.

servers). H. probably showed the effects of practice more than any other. For her, the first three discs were black on the outer ring, with *possibly* a tinge of dark green; on the fourth disc there was a tinge of violet *at first;* discs 5 and 6 were black; disc 7 showed blue; 8 a green-blue. Afterward the green became less prominent, until it almost disappeared. Be. noted that the colors were better after looking awhile. For H. the lighter greens of rings two and three were very apt to change and hard to hold. O. saw the greens before any other colors, and his reports corresponded most clearly with the length of line. For W. the reds and blues were so brilliant that the greens by comparison could be said to have almost no color at all. The individual peculiarities continued throughout, so that they could not be said to be due to accidents of the discs.

§ 3. Rate of Rotation.

As is noted elsewhere, the effect of very rapid rotation is to produce a uniformly shaded surface. This effect was also studied by means of disc 3 which was divided into quarters. All of the colors became duller, "dirtier." Ring 3 (the outer one) was changed most. For B. it was a light green; H., black; M., black; O., black, maybe some blue; W., violet. Aubert gives an exhaustive account of the effect of rotation, working with the well-known disc with two divisions in ring one, to sixty-four in ring six.[1] When the discs are "slowing down," *i. e.*, when intermittence becomes less frequent, the colors change in brilliancy, and just before stopping, when the colors have entirely disappeared, the black lines appear very intense.

§ 4. Length of Line.

This study was made with discs on which there were shorter or longer lines than was ordinarily the case. The discs used for this study were: 8, 13, 16, 17, 18, 19, 20, 21 and 25.

Red. When the lines are lengthened the color is darkened. Colors were matched 11 times; of these 9 were taken from plates IV or V, in comparison with choice from plates II and III, sometimes IV, chosen for discs 1 and 2. Of 30 reports, including verbal descriptions and matched colors, all but one modify the report "red" by adding "there is much blue," or "black," or "red on the border only."

In disc 25, ring 1 (passing through one sector), the red is faint; ring 2 (passing through two sectors) is a deep red, redder than 1; ring 4 (passing through three sectors) is only faintly shaded with red for S. Be. can "suggest" red better than green or blue; hence might suspect the presence of red.

[1]Aubert: *loc. cit.*

W. reported "no blue at all," showing that red was not even remotely suggested to her. These results are quite in accord with the results obtained by varying the amount of black on the disc (*cf.* § 5). It is simply another way of changing the duration of stimuli.

Green. Here again the colors are darkened, with an occasional increase in saturation. H., *e. g.*, reports II g as a match for ring 3 disc 8 (lines 1 ¼ sectors long) when reversed. This is the only color chosen from a plate with very saturated colors. 25 times the colors were chosen from plates IV to VII, and only twice from plate III. The adjectives used were often such words as "dirty," "nondescript." The changes which occur here are also in harmony with the changes brought about by changing the size of the black sector. In disc 21, where the lines were preceded and followed by equal amounts of white, the reports were VyO, IVyyg1, Vyg1, but it was added that this was just at first; the colors soon became bluish. In the reverse of disc 19, where the lines passed through the first half of the fourth and all of the third sector, the colors were reported either as blue from the first moment, or as changing sooner than in other discs. H. reported all sets of 19 as varying from VII RRv to VI v, *i. e.*, as having only a faint tinge of color. W. reported all as gray. In the reverse of disc 20, B. reported ring 1 as V BG1, and ring 3 as V BG1 to VvRv1. H. reported ring 1 as V GBG, from memory, but after this first moment as VI Bv. For W. they were all gray with some red. Ring 4 of 20, with the clock-wise turning, was reported by B. as green with some red, by H. as "a very deep green which stays," by M. as "green and quite saturated," by O. as "a distinct green." The effect of the length of line upon the green is to *darken* it, but *not to decrease* it in *saturation*.

Yellow. It may have been noted that the yellows are almost never reported as pure yellow. If it is remembered that yellow where mixed with black gives a rather greenish effect, a "dirty, nondescript" color, this fact will not be counted against our theory. The reports upon green are often modified by the adjective "yellow." No less often is the report upon yellow modified by the adjective "green;" for a yellow mixed with a black is, by this decrease in brightness, given a greenish tone. Furthermore we are little accustomed to seeing this color mixed with black. A dark blue or a dark red is recognized as being mixed with black, and such mixtures are matters of everyday perception. The same is true, too, of green; but we do not often find yellow mixed with black. We have either the pure color or light yellow, "canary," "lemon," "corn-color," etc. The reports "dirty, faded green," "nondescript," etc., are almost always referred to some modification of yellow when these

are matched. A special study of the yellows was made with the disc with a movable sector, also with discs 35-38. (The report is given below.) In disc 19, B. reports all sets as yellow, but very dark; but H., M., O., and W. report them as gray, not a dead black and white, but a gray modified by some color which they are unable to name. In disc 20, however, where there are other colors with which to contrast these same lines, ring 1 is reported by B. as olive-green, by H. as a green which soon becomes violet, by M. as dark green, by O. and W. as gray with some red. Ring 3 is reported by B. as having lines 2 and 4 a blue-green, and 3 a red-brown; H. and M. report a green which soon becomes violet; O. a black-gray; W. gray with some red. When disc 20 is reversed, ring 4 is reported by B. as V B3, by H. as VIvBv, by M. as IV Bv3, by O. as V Bv1, and by W. as being reddish.

This change into the blue tinge, which is always very faint and dull, is also in correspondence with the results obtained with the discs with the varied black sector. In order to eliminate the factor of black, and to ascertain certainly that green appeared on ring 2 and yellow on ring 3, a series of four discs was made such as is shown in the Plate, discs 35-38. At first glance By. reported ring 2 of disc 35 as green, ring 4 as a faded yellow-brown; later she said she believed it was a green-brown, but after looking again when rested said it was yellow-brown. Be. matched the second ring with IV GB6 or GBG6, adding that the disc color was a little lighter; and matched the fourth ring with IIIy6, adding that the disc was lighter than this, too. By. called ring 2 of 36 a "faint, washed out" green, ring 4 a green or yellow-brown. With indirect vision, or while looking at ring 2, By. could see green in ring 4. Be. hesitated about ring 2 for some time, wondering whether there was not some pink. He was expecting green, for the ring was next to ring 1 which was a very rich blood red. The red comes in ring 2 only occasionally, and has in it no purple. Ring 4 he called a light brown (*i. e.*, yellow in some gray), IIIyO6, and said it was darker than ring 2.

In disc 37 By. reported ring 2 as green, ring 4 as pink at first glance. Ring 4 soon grew greener and duller; but as she looked at ring 2, the color became brown again. Ring 2 matched most nearly IIIyG6, ring 4 matched IIIyO6. For Be. ring 2 was green at first (and he noted that it was greenest just as he "goes to look" directly), and after a rest matched IIIyG6 (just as By. had matched it); ring 4 was a yellow gray-brown, darker than 2, and maybe a little red. At first Be. chose IIIyO6 to match ring 4, but later changed to IIIy6, because the *yellow* was more prominent than anything else. In disc 38 the green of ring 2 was for By. much more yellow than

before and easily lost its saturation; it was matched with IIIyy6; ring 4 was much darker than ring 2, was yellow-brown with the two inside lines "quite a good green," but matched IIIyO4. Be. matched ring 2 with IIIy6 as nearest; he added that it should be greener, but yyG6 was too green. He took some time to match ring 4. It was nearest IVy4, yet he said he was *sure* there was some green in it.

These results show quite clearly that it is green which appears most plainly in sector 2, even though it is a yellow-green. The yellow undoubtedly appears when the lines are in sector 3. The fact that both Be. and By. called ring 4 of 38 *green*, and were surprised when it matched a yellow, shows that there is a natural tendency to call yellow *green* when it is mixed with black. This result is also in harmony with the Purkinje phenomenon displayed by yellow when darkened.[1]

Of course, these colors were very light in comparison with the red and blue of rings 1 and 3, on account of the very short lines. The positions of the red and blue were kept constant, so that we could be sure that any change of color was due to changes in the lines themselves.

The relative values of the green and yellow were studied with W. and S. by help of disc 26 with the movable sector. The lines were thin and farther apart than usual, and three in each group. There was no decided green or yellow for W. at all. According to the method of minimal changes, the black sector was varied from $\frac{1}{2}$ to $\frac{1}{16}$ and *vice versa*. When the disc was $\frac{5}{16}$ black, W. noted that there was scarcely any red in 1, and that the blue was very much bluer; with $\frac{1}{4}$ black, there was no more red in 1 than in 2; 3 was very much lighter than any of the others and bluish; the blue was much bluer.

[1] An attempt was made to obtain, by use of the Hering mixer, some sort of an equation between the green of yellow when mixed with black, and green itself mixed with black. The experiments were made in day-light and with the Hering color papers. It was first determined that to yellow must be added 20° of black in order for the yellow to appear greenish. 16° of yellow must be added to the black before it begins to appear greenish. Black was then added to yellow and yellow to black in order to obtain the mixture which seemed to contain the greatest amount of green. This mixture was found, on several different days, to consist of 131° of yellow and 229° of black. With this mixture was equated the mixture of about 5° of white, 300° of black and 55° of green. 60° of green made the yellow appear to be reddish, a sort of orange yellow; while with 50° of green the yellow made the green appear to be blue. Hence in the former case there was too much green, and in the latter there was too much yellow. Accepting, then, the comparatively rough estimate of 55°, we may say that the color in the mixture of 131° of yellow and 229° of black might appear half green. We may say that the resulting color is a yellow-green or a green-yellow.

This was the same with the reverse. With S., when three was ⅛ black and the disc was being reversed, there was red-yellow on ring 3; with $\frac{3}{16}$ black, ring 3 was green-yellow. All the other rings were darker, but less distinct as regards color. This method did not prove to be so satisfactory as the one usually followed.

Blue. The effect of change of length upon the blue can be reported only in a general way, for it will be remembered that it was impossible to match the blues with any degree of accuracy. Very often the comparison was attempted, and in almost every case it was I B or BBv for saturation, but plate IV (or VI or VII) for brightness, as the case might be. We have all seen very rich dark blues, and know that mixture with black does not at all necessarily mean dullness or deadness, lack of lustre or life. It was noted, however, that when this change in brightness came there was often the remark, "now maybe I can match this." This plainly showed that a change was recognized. When disc 25 was reversed, ring 1 became a slightly green-blue, ring 2 was the usual violet-blue, ring 4 was faintly blue (perhaps by suggestion from rings 1 and 2) or black. For S., however, the ring took on the faint tinge of "chocolate" so often seen on the red lines. It is quite in the order of things that red should appear here, where we have a small section of white between black sectors and black lines,—but it is so faint as to be ordinarily overlooked, and is "suggested away" by the brilliant blues of rings 1 and 2. The change with the blue is again similar to the change with the discs carrying the small sectors of black. The blue is *dark*, but still *rich* in *saturation* and *luminous*.

§ 5. Variation of Size of Sectors.

After it was found that the length of the line caused some change in color-tone, a series of discs (26-34) was made in which the length of line was varied proportionately with the size of the sector. This proportionate variation was brought about by making discs on which the amount of black varied from 0 to ⅞. There was also a disc with the four groups of lines drawn as usual on the white, but with the black part made as a movable sector. This series of discs serves for a study of the length of lines, the effect of alternation and duration of stimuli, and also for a correlation of brightness of disc with the Purkinje phenomenon. Disc 27 is shown on the plate. On the remaining seven discs the white part is divided into four equal sectors, on which are drawn groups of arcs of the same size and radial distance as in Fig. 1 of the plate, but varying in length.

The disc which was ⅜ black varied only slightly from those

1

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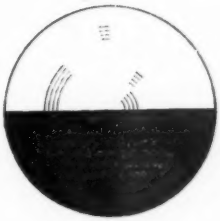
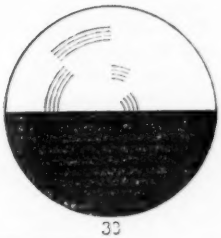


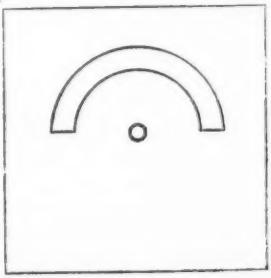
35

36

37



38



2

which were ½ black. Change took place most rapidly with *increase of black*. There was a significant change in the way the reports were given. It was the darkness which first caught the attention. (The observers were all inclined to describe any striking feature before beginning to give the systematic report, and not seldom there were exclamations of pleasure or surprise.) The disc which was ⅝ black was described as looking smoked, or as if the colors were deadened by being seen through a dark veil; the black seemed to "interfere" with the brilliancy of the colors. The red was darkened for all observers by the presence of black; the lines which were usually green took on a rather pinkish shade, and were described by Be. as IIyyO5 (a very light orange), by S. as VyyO3, and by W. as a yellowish-pink, a sort of pale salmon.

The most striking change was with the disc which was ¾ black. The first unstudied impression was a dull, unsaturated red, or faded pink. And the fact that the second ring had become the brighest red and the most saturated color on the whole disc invariably caused surprise. It was reported as V Rv4, V O5, most decidedly the reddest, unsaturated but unmistakably red, a faded but uniform red. The third ring was described by three observers as green (including W., who seldom saw any tinge of green), but by one was reported as pinkish, of the same general tone as the first and second rings but more faded.

The disc which was ⅞ black became upon rotation a dull, hazy red over its entire surface. Rings 1, 2, and 3 were all of a dull red shade, 1 least saturated, 3 most. Ring 4 was at first faintly green, of a very dark shade, but it turned to red if the observer looked too long. Through this part of the series we see that the blue and yellow lines are very soon changed as regards color-quality, and that the red especially, with short duration, tends to color all the lines. The colors are thus not *dependent merely upon their position* (alternation of stimuli) *but in addition upon the actual duration of the stimulation.*

When the amount of black was decreased, the colors tended to be of a saturation equal to that of the discs ½ black, with the green perhaps lighter. Be., for example, reported ring 2 as IVg when the disc was ⅜ black, and IIg when there was ¼ black. S. also reported vivid green for the latter disc, and by matching reported IIIyG; but for the former reported only IVyyg2, and described the green as more yellowish than when there was only ¼ black. W. made no distinction between rings 2 and 3 of these discs. The red and blue were both saturated, but the green and yellow lines were reported when there was ¼ black as rather violet-gray. With clockwise turning the green was faint on ring 2, but with reverse turning both were violet-gray. With ⅜ black, rings 2 and 3 were mottled red and

very dark green; with reversal the reports for both rings were gray, with red here and there and possibly some green. At least the green for W., even though faint, was enhanced by darkness.

Ring 3 with the disc ⅜ black was different for all observers. It was hard to hold, therefore hard to match and to describe. It very evidently had an annoying, irritating effect upon the observers. They frequently asked to rest and hesitated for some time before reporting this ring as blue. Occasionally it was described as at first glance a faint yellowish-green, but this lasted scarcely more than a second. The verbal reports were blue, blue in gray, stone-blue, etc., but when the colors were matched they varied from IIIv1 with Be. to III BBv4 with S.

The disc which was only ⅛ black was accompanied by an unmistakably pleasant affective tone. The colors were reported as mixed with black, on account of the length of line, but the "spots" of color that could be separated from the black were described as *very* saturated and pretty. (It was noted that *pretty* was almost always applied to the more unmixed colors. Those that needed several adjectives to describe them, or that were hard to match, were reported more often as unpleasant, unsatisfactory colors.) The blue of ring 3 was reported as IIIvBv2 or v4, as not a very unsaturated blue or lavender.

When there was only $\frac{1}{16}$ black, the red became plum color, the green was still green although very dark, rings 3 and 4 were blue. The observers were asked not to look at the disc until it was in full motion although the change from more to less black was easily recognized. It was especially desired that they should know the construction of the disc with no black whatever, before the reports were given. The rings were reported at first as blues, or as black; but after attentive observation for a moment or two, rings 1 and 4 were reported as blue, rings 2 and 3 as green (3 perhaps as both green and violet). The green faded more quickly than the violet. There is no beginning or end to the disc. The alternation is the only feature which can differentiate greens from blues. Rings 1 and 4 may be either red or blue, but ring 4 will be darker because the lines are longer. S. was the only observer who reported a faint tinge of red in 4.

Although these subjective colors depend upon duration and alternation of stimuli, they are not all of the same saturation or brilliancy. We may permit ourselves to use the expression "mixed with black," because there are changes in saturation due to changes in the black sectors which govern the time for regeneration of the visual substances, and in the white sectors which change the duration of stimulation. The colors are mixed with black just as any subjective color is mixed with its

background. In the discs the background is either black sector or black line.

It will be noted in the above that there is a striking illustration of the Purkinje phenomenon. With *increase of black* the long-wave end of the spectrum is emphasized; there is much red, but only little green. With *increase of white* the short-wave end of the spectrum is emphasized, the long-wave end is lost. But, contrary to the phenomenon under other circumstances, the green becomes very saturated (vivid myrtle) although very dark. Our brightest light is much more moderate than the light required to make the spectrum appear blue and yellow.

§ 6. Effect of Width of Line.—Discs 2, 4, 6, 7, 9 and 22.

We may report that, as a general rule, the width has little or no effect upon the color. If the line is very thin it may seem "hard to get hold of," not enough mass to give color; but this varies with the observers, some of whom prefer the broader, others the narrower lines. Slight changes in width had no appreciable effect. W., who saw "red edges" on almost every disc, continued to see red only on the edges when the width of the lines was increased. H. and M., who almost never saw red on the edges only, saw wide lines as entirely red. B. saw red edges on the fine lines of disc 6, not on the wide lines. Disc 22 certainly had lines wide enough to give a crucial test. Here B. did see red edges, the outer edge more saturated; Be. saw a yellow halo just outside the red ring, but the ring itself was a reddish-yellowish-brown; S. saw ring 1 as plum color; O. as a brown-gray, lighter at the edges; W. saw it with red edges as usual. But for all the second ring was greenish, the most saturated on the disc, colored *all the way through*. For W. there was some green in it. Ring 3 was a blue-gray for all, for B. and O. it was lighter at the edges, for W. bluer. Ring 4 was a deep violet for all, especially marked at the inner edge. These lines are so wide that they might very well show contrast with the surrounding white field, while on the narrower lines this contrast would not exist separately from the general color-tone of the whole line. That red should appear at the edges is quite in harmony with our statement that red appears with cessation of a black sector or with beginning of excitation.

We choose at random a few cases to illustrate our statement that width has no especial effect upon color: discs, 2, 4, 6, 7.

Table II.

Red.	B.	H.	M.	O.
2.	IV RRv	III Rv	III Rv	IV RRO
4.	III RRv5	IIv Rv4	III Rv3	IV Rv4
6.	II Rv	III Rv	IV R1	IV RRO3
7.	III Rv1	IIIv	IVvRv	V RO1

TABLE II.—*Continued.*

Green.	B.	H.	M.	O.
2.	VgBg	IIyg	IIIyg2	IVyyg
4.	Vyg5	IIIyO3	IIIyg1	IVyg
6.	IVgyg5	IIIgyg1	IVgyg2	IVyg3
7.	IIIg3	IVg2	IVyg1	IVyyg2

§ 7. EFFECT OF POSITION UPON THE DISC.

There is at least one very striking effect due to variation of position of the rings upon the disc. The commonest arrangement is that represented by Fig. 1 of the Plate, and this is the best arrangement. We stated at the beginning of our investigation that reversal of the direction of rotation of the disc had no effect upon the general color-tone. It has, however, an invariable effect upon the shade or tint of this tone. The first ring of Fig. 1, when not reversed, gives a brilliant blood-red; but when the direction or rotation is reversed, the red becomes brownish or purple, *i. e.*, tinged with blue. The fourth ring, when not reversed, gives a brilliant, luminous and rich blue; but when reversed a duller, more violet blue. In other words, when there is reversal, the red appears in ring 4, where there is the same proportion of black and white as in ring 1, but where there is an *increase* in the *actual amount* of *white;* the blue appears in ring 1, where there is an actual *decrease* in *stimulation.*[1] This is again in accord with the results obtained with the series of discs made with greater and lesser amounts of black (*cf.* § 5). For example: B. described ring 1 of disc 1 as brilliant blood-red, but upon reversal it became III-RRv; H. described the same ring as a brilliant lavender, luminous purplish-pink, but also chose III RRv; M. chose IV R to match this ring, while before reversal W. chose II R. Disc 5 ring 4 B. described as indigo, but matched it upon reversal with IV B. Disc 5 ring 4 O. described as black, but on reversal matched ring 1 with I BBv. Disc 6 ring 2 H. described as a "deep, rich green which very seldom changes," but upon reversal matched ring 3 with IIIgyg1, and added "it soon loses its green." The same green M. described as "quite satisfactory, best green so far," but matched it with IVgyg2. In another section we have already found that length has an influence upon color, when the discs are turned clockwise and reversed,

[1] Discs which are made of plain sectors of black and white upon rotation become a uniform gray from center to circumference, but when the sectors are notched or toothed, the conditions are changed even though the proportions of the brightnesses are still equal. Sherrington, Jour. of Phys., XXI, 1897, 47, shows that these temporal relations also effect degree of flicker, and proves that the direction of rotation changes the time of persistence of flicker.

Contrast with the colors of the neighboring ring has a slight effect upon the color. Discs 13, 15, 19, and 21, which have all lines arranged so as to produce green, were described as "monotonous, unsatisfactory, unpleasant." The effect was often very slight, because the influencing colors are themselves often only weakly saturated. It was often difficult to distinguish the cause of saturation. Take, *e. g.*, discs 11 and 12: ring 2 in disc 12, with ring 3 red, was described as light olive, vivid and rich, olive with gray; ring 4, with ring 3 red, was described as deep olive, saturated but not pure green gray. Ring 4 of 12 had the advantage of position over and above the contrast common to the two; yet ring 2 of disc 11 was described as the more saturated, or at any rate as not less saturated than ring 4 of 12. Again in disc 17 green appeared on rings 1 and 3 with red on 2 and 4; B. reported 1 as pale green, 3 deeper than 1; H. described 1 as almost pure green, while 3 was not so deep; M., too, described 1 as dark and saturated, 3 as blue-green, lighter and thinner than 1. Here some of the individual differences appeared. Ring 3 for H. and M. was more apt to become violet than was the case with B., and the advantage of having red on either side could not overcome this tendency.

§ 8. Contrast: Effect of Gray Screen.

In order to study the effect of contrast gray screens were made; one of these is shown in Fig. 2 of the Plate.

The screen was a neutral gray paper on a stiff cardboard large enough to cover the disc. A small hole in the center fitted over the screw of the spindle, so that the card could be held back close to the disc,—so close as to avoid shadow, yet not close enough to interfere with the turning of the disc. There were seven screens, each with a semi-circular opening wide enough to expose one ring of the disc: four, of course, were needed for the four-ringed discs, and three for the three-ringed. Besides cutting out the remaining rings, the gray screen also cut out the surrounding bright field of the whole disc. (The experimenter often noticed that the colors were more brilliant when the lamp-light shone in the face.)

The general effect of this screen—excluding contrast both with ring and with field—was to *decrease* the brilliancy of the color of the ring. M. studied only a few discs in this way, but the few results obtained were remarkably uniform. The reports for the reverse of discs 9 and 11 are given as illustration.

M. remarked that rings 1 and 2 of disc 11 were different when seen together, 1 being darker and greener.

The most extensive studies with the gray screen were made with B., O., and W. as observers. In all cases the rings were

TABLE III.

	DISC 9.		DISC 11.	
	No Screen.	Screen.	No Screen.	Screen.
Ring	1. IV R	IV RRv1	1. IIIyg1	IVyg4
"	2. IIIgyg2	IVyyg4	2. IIIyg3	IVyg4
"	3. IIIyyg4	IVy4	3. I BBv	IV BBv3
"	4. III BBv	IV Bv2	4. IV RRO1	III ORO2

reported on without the screen (these reports are not included in Table I), sometimes before the screen was put up, sometimes after, sometimes both.

In general the result is as noted above. O.'s results were most marked with respect to the greens. He was shown discs 5, 7, 8, 9, and 10. In all cases except disc 7 the green lines were reported "gray," without the screen "green." In disc 7 there was "a little green" with the screen, without the screen it was "greener." Rings on discs with colored sectors became "more saturated."

The most notable fact in B.'s results was that with the screen the blues were apt to be very green. In discs 1 and 10 the lines were black, in 5, 7, and 9 green-blue. The reds were least, and the greens most affected by the screen.

W. observed discs 1-25, and 30-33. The reds were least dulled or changed by the screen; the blues were less blue and bright; the greens were most changed, often losing entirely their faint green cast, and sometimes even the "red spots here and there." It was noted that toward the latter part of the investigation W. reported "no change" more often than during the first part.

More detailed investigations were made with discs 13, 15, 19 and 21. Since the rings are dulled or deadened by being all alike, it was thought that the screen might help to increase the saturation by relieving the monotony. But the effects of the two must be about equal, for the colors are the same with and without the screen. W. reported that disc 13 was greener without the screen; disc 15 showed no color difference but a brightness difference,—less bright with the screen; disc 19 showed no change, all rings were blue-gray with spots of red; disc 21 showed more red than 19; and W. noted that in ring 4 there was less *red* with the screen, if there was any change at all. Be., with disc 15, saw all lines as possibly green-gray with red here and there; the screen decreased the red. Contrast effect was manifested very slightly in the spaces, more often within the groups than between them. For O., B., and W. this influence was very slight, and (except occasionally with the blue, when the blue seemed to tint the spaces) they did not speak of it unless they were asked. For H. there was more color, but for M. there was most: she of her own accord

reported the colors of the spaces just as systematically as of the lines themselves. The yellow of the white sector was apt to give its tint to the whole disc, especially at the outer edges. The reds had faintly green (blue-green, or yellow-green) in the spaces, the greens had reddish or lavender spaces, the blues seemed almost always to give their own color to the spaces. The blue was the strongest generally, but all of the tints were very nearly liminal.

§ 9. Day-Light and Decrease of Lamp-Light.

The experiments made in diffuse day-light can scarcely be compared with those made in artificial light, but they may serve to show the effect of increased light. All colors except the blue were faint. The reds were reported as brown, or blue-red; the greens as gray-greens, often there was not a trace of green; yellows were never reported by this name, but either as light gray-green or (more often) as light slate blue or lavender; the blues were rich, luminous, violet-blues,—richer than simple dark blue would be. The artificial light was not decreased by exact measurement, but changes were roughly estimated. The effects were studied with disc 1. When the light is turned only a little lower than that ordinarily used, ring 1 becomes *very* dark red, 2 a pinkish-yellow, 3 a black with maybe a tinge of red. Further decrease makes ring 2 the reddest. Again decreased, ring 1 becomes dark green, 2 a blue-green which turns to pink, 3 a very black-green; decreased still further, 1 is a very rich deep green, 2 a smoked pink, 3 red at first glance turning almost immediately to green. When the light is almost out, the color of ring 1 can scarcely be distinguished from that of ring 2, but after a few seconds 2 becomes a lighter pink, 3 is darkest of all and is greenish. When the light is turned constantly and gradually, the observer watching all the time, the first change is to a yellowish effect, then to a pinkish all over the disc. At this same moment the red (ring 1) changes almost instantly to green; the green a little later becomes yellower, then red, and at the same time the blue (ring 3) becomes a red purple. With further decrease, the green of ring 1 becomes a very deep red, and 3 becomes green (but when the observer comes very close to the disc it is seen to be a black-red). The whole disc, just before the light goes out, has a very dark, faintly reddish shade.

These changes are at least roughly in accord with the Purkinje phenomenon. With day-light the lines become bluer, with decreased light they become redder or greener. These results are also in accord with those given in § 5.

§ 10. Colored Background.

After having ascertained that the color of the lines is conditioned by the alternation and duration of black and white stimuli, a series of discs was prepared on which the lines retained positions similar to those in the preceding series, but in which a portion or all of the white semicircle was replaced by a background of one or more colors. Almost from the outset there was evidence of a strong effect of simultaneous contrast. This continued so constantly and so similarly with the different observers that the Helmholtzian explanation was out of the question. Since a consciousness of the backgrounds is inessential for simultaneous contrast, we cannot hold that it is an instance of *Urtheilstäuschung*. We must hold with Hering[1] (as well as with Fechner[2]) that simultaneous contrast depends not only upon the stimulation of a certain part of the retina, but also upon the stimulation of the surrounding portions of the retina. Sherrington, at a much later date, emphasizes this same fact, and adds that this reciprocity is *subconscious* in origin yet affects consciousness.[3] The fact that the color of the lines depends upon co-excitation is more evident here than with the black and white discs. It was also noted in § 8, that the gray screen had a greater effect upon discs with colored backgrounds than with the plain ones.

The discs upon which appear only a single background color (sets I to V inclusive, and set XIII) are more instructive for the investigation of contrast effect than the remaining sets, because they avoid complications. For the sake of convenience, we shall continue to speak of the lines as red or green or blue in order to designate their positions, although as a matter of fact these colors under certain conditions are entirely lacking. For the sake of uniformity, the colors will be studied in the order of red, green, blue and yellow, as regards both sectors and lines.

A. When red lines appeared upon a red background the quality was entirely changed. If we remember that the complement of red is a bluish-green, and if we take into account the fact that for some of our observers green is very rarely present, we may say that *when red appears upon red the lines become complementary to the surrounding background.* When the white background was entirely replaced by red, in which case the fused background became very dark red, the complementary green was also very dark, rich and well saturated. On

[1] Hering: Lehre vom Lichtsinne, Pt. II, 1878, § 11. Also in Sitzungsb. d. kais. Akad. d. Wiss. Wien, 1872 and later.
[2] Fechner, G. T.: Pogg. Ann., *loc. cit.*
[3] Sherrington, C. S.: *op. cit.*, 38.

the other hand, if, *e. g.*, only one sector was replaced by the red, so that upon rotation the background was a light red, the lines became correspondingly light, and took on a light green-blue or blue-green that is difficult to classify. The observers were inclined to call it green-blue, but often remarked that they were not sure which color predominated. When the colors were matched they chose blues, very light, as, *e. g.*, Ib5. M. chose IIbbg2, but named it 'baby blue' even after she knew that green was present.

If, then, we leave these variations out of account, the red lines on the red background became the complement 36 times out of 39. O., in disc I 1, said the lines were slightly red, and W. reported gray once and black once. When red lines appeared upon a white sector, with red upon another, the result is practically as it is when there is no colored sector. Red was reported 28 times out of 29, green reported once (O.). When red lines appeared upon a green background, red was chosen 31 times out of 31. To be sure, the shades of red varied from a good red to a violet or dull rusty brown, but the descriptive word was always red. When red appeared upon white with blue in another sector, red was chosen 27 times, green twice, blue-green once, yellow once, and black once. The color was never pure, and there was almost invariably an unpleasant affective tone. Such adjectives as rusty, chocolate, brown, dull, unsaturated were used to modify the report 'red.' On the other hand when the red lines appeared upon white, with yellow in the background, red was reported 22 times, yellow once (B.), and this was a deeper, richer yellow than the ground. In every case the affective tone was pleasant. The colors were dainty, light yet pure, luminous, rich and brilliant.

B. When green lines appeared upon a green background, we found no such precise uniformity as with the red lines. Still, they may be said to follow the same law. When green lines appeared upon the green background, the complementary was chosen only 17 times out of 30; 9 times green was chosen, twice the lines changed almost immediately *from* green *to* red, and 3 times red and green were combined,—not fused, but appearing in different places upon the same line. Of the 9 times when green was reported, 5 concerned lines on disc 12, where the entire semicircle is green. In one other case *green* followed the lines. In 3 cases there were two sectors of green, but white followed the sector upon which the lines appeared.

From this we may draw the conclusion that the green, which we found with the black and white discs to be very weak, is not able to assert itself over and above the effect of the background color.

It should be noted that the green was very instable, that it

was very apt to become lavender, or even decidedly red. When green lines appeared upon red they remained green. These rings were often compared with the red lines on the red (which we saw became green or blue), and the green lines were found to be *less* saturated than the red. The green was the same light blue-green. For O. and W. the lines were occasionally orange or red in gray. The green lines upon blue were reported 22 times as a bronze or a yellow-green shading toward orange or pink. But it was always an unsaturated color, matched either with plates IV or V, or with rows 5 or 6 of the chart. Green upon yellow was reported 26 times as very light blue-green or green-blue, 4 times as gray with flashes of green. When green appeared upon white, with red in the background, red was reported 29 times; with green in the background, green was reported 18 times, violet only twice; with blue in the background, 8 reported green (including gobelin blue), 5 said blue, 4 red, and 1 black,—the colors were usually dark; with yellow in the background, green shading to yellow was reported 29 times, twice a combination of red and green, the colors being usually light and unsaturated.

C. When blue lines appeared upon blue, we found again a law similar to that governing red. The reports varied from reddish-brown to VI OrO, a very dull orange, and were given thus 39 times; twice there was described a royal purple surpassing any color on the chart in saturation and luminosity. Usually the colors were very hard to match on account of their low degree of saturation, and were accompanied by an unpleasant affective tone. When blue lines appeared upon a red background they became a very rich, luminous blue-green. The reports I b 1, I b 5, IIbbg 3 show that they were very light and that there was a tendency toward green-blue. When blue lines appeared upon a green background they became a dull reddish-violet (VIIrrv) tending toward a dull orange. The complement of the background color added its effect to the lines with both green and red. When blue lines appeared upon a yellow background, the color of the lines and the contrast effect reinforced each other and a rich, navy or indigo blue resulted.

When blue lines appeared upon white, with red in the background, they became a deep rich red-violet, rv, or IV r; with green in the background, they became brighter, IV bv, I bv, or IV to VII bg; with blue in the background, the color of the lines was enhanced, and became a rich wine, or purple, or violet; with yellow in the background, the blues became greenish III bbg, III bg 5 or 6, III b, usually colors of a rather high degree of saturation.

D. Yellow lines upon yellow follow tendencies similar to

those of green upon green. Blue was reported 5 times, blue-green twice, combinations of green and red twice, yellow-gray to yellow-green 14 times and gray twice. Yellow lines upon red became blue or blue green, very light and bright; upon green, a pale, dirty green when a white sector followed, but when a green followed the lines became orange or even purple; upon blue the lines were yellow, varying from a good yellow to a pink orange. When yellow lines appeared upon white, with red in the background, the lines became reddish, but more yellow if a white sector immediately followed the lines; with green in the background, the lines too became greener than usual, so that even W. saw quite clearly a tinge of faded green; with blue in the background, the lines became a deep indigo blue when blue followed immediately, but they became more reddish (rv) if white followed immediately; with yellow in the background the lines were a dull yellow, a sage green, occasionally tending to change to a reddish or bluish cast.

E. Where there are *2 colors* in the background, the lines are brightened or dulled according to the relation existing between line and color; *e. g.*, in discs VI 1-3 the red lines on red (2 red, 1 green sector) were such a dark red that there was scarcely any color for B. and H.; M. could see both red and green occasionally, which gave a gray effect; W. matched the lines with II bg. In VI 2 the red rings were still on red (2 red, 1 blue sector) but took on a very unsaturated blue-gray color for all,—only for an instant was it green for B. But in VI 3 the red ring became a dark and unsaturated green (2 red, 2 yellow sectors) for B., for H. a greenish-blue, for M. a light blue-green with occasionally the red and the yellow of the background coming over it, for W. a bright blue matching I b 1.

But when VI 1 was reversed, this threw the red over to ring 3 which was *on* green. This means that the red lines will be bright by contrast, and evidently this red is not dulled when the red sectors follow. B. reported II r, H. V r, and M. IV r with more red.

Ring 2 of this same series of discs showed also that, if the ring color was brought out by a complement, and was then followed by its own color, it was enhanced. VI 1 ring 2, green on red, with regular turning was followed by red. The report said that it was a beautiful, dainty green, apt to be bluish, a little lighter than grass-green, and W. matched it with III bg 2. But upon reversal both B. and M. chose IV gyg to match it, and H. IV yg. (This is quite dark, yellowish and unsaturated.)

Similar facts with other colors appear on other discs. XI 3 ring 4, *yellow* lines on *yellow* with *blue* following, was for B. on lines 2 and 4 blue, and on lines 1 and 3 brown, for H. green,

for M. faintly yellow green, for W. vbv. Reverse of disc VIII 3 ring 2, *yellow* lines on *blue* with *blue* following, for B. was III yyg 4, for H. IV O 4, for M. II OyO.

VIII 3 ring 2, green lines on *blue*, yellow following, was for B. green, H. green, M. y-green, W. blue and red.

XI 3 ring 2, green lines on yellow, yellow following, was for B. navy blue, H. red-violet, M. black-red, W. dark red, III v.

VI 3 ring 2, green lines on *red*, yellow following, was for B. light green with some red, H. blue-gray, M. pale green-yellow, W. an unsaturated blue.

On all of these green has not the proper circumstances to bring out its color well. Contrast the above with the reports given for X 1 ring 3, green lines on *red*, green following; for B. green, lighter than grass-green, matched I gbg1; for H. slightly green-blue, matched II gbg 1 (and sometimes gyg); for M. saturated green, matched IV g; for W. I gbg 2. These colors were reported and matched on different days. The very striking similarity between reports cannot but be noted.

Analogous descriptions could be reported at tedious length, but these are sufficient to prove the point with which this part of our discussion began. The lines are brightened or dulled according to the relations existing between the color of the lines and the colors of the background, This serves to illustrate again the fact of contrast, which appeared in the preceding discussion. It shows, as did the preceding part, how very rapidly the different excitations produce their effects. and how infallibly certain sectors (which denote certain durations of stimulation) take on their own proper colors.

Our *general conclusion* from these detailed reports will then be as follows. 1. When the lines appear upon the background of their own color-quality, they take on the color complementary to the background.

2. When the lines appear upon a white background, with a color in the background, they have practically the same color-quality that they have when the disc is plain black and white, but they are affected by a colored background according to the laws of color mixture. That is, when the color of the lines is complementary to that of the background, the color of the lines becomes duller as a result of the mixture; but when the color of the lines is related to that of the background as a neighboring spectral color, then the color of the lines becomes a mixture of the two,—brighter or duller according to the qualities of the colors mixed.

V. Theory.

There are, without doubt, numerous other ways in which the phenomena of Fechner's Colors might be brought about, and there are many other ways in which the discs might be varied. But the important point is to discover the conditions upon which the colors are dependent; as a corollary to this followed the investigation of the conditions which served to bring out the colors in the best way possible, to produce the greatest possible saturation and purity of colors. The use of fine lines upon a white background is much better for the production of clear-cut colored areas than the use of large blocks of black and white, and better than cutting out sectors from either black or white discs. Both of these methods give larger masses of color, but the extent of colored surface can be determined with less accuracy, and variations can be made less readily. Further variations, but also greater complications, could be obtained by the use of a greater number of colored backgrounds and by the use of colored lights.

Our aim has been to avoid such complications as might lead to confusion of results, and thus obscure any law which might appear with greater simplicity of conditions. It is under very simple conditions, then, that we have obtained the preceding facts.

The phenomena of the discs cannot be disputed. Given the conditions of illumination, rate and construction of the disc as described, one can predict infallibly the general color tone which will result for the normal eye. There can even be predicted the result for the fatigued eye But this is only to state the problem, not to solve it. A theory must state the special conditions upon which the appearance of a quality in consciousness is dependent, and these conditions must necessarily be sought in specific bodily dispositions and functions. Hence we have turned to the theory of vision proposed by Ebbinghaus, because it brings us nearer to these bodily dispositions and functions than any other theory yet advanced.

The theory of fatigue must be abandoned, for the colors take on their greatest saturation at about the time required for perfect accommodation (upon the disc, not the lines), and *lose* their saturation as dissimilation continues. We cannot agree with Helmholtz that a certain amount of fatigue is necessary for the perception of the colors. The theory that the colors are due to sympathetic excitation must also be put aside. Red may be due to some extent to this cause; but there surely is no reason to think that sympathetic excitation would act in such a way with one set of lines, while the one following next to it gives the very opposite color. Hence another explana-

tion must be sought for the three remaining rings of the disc. If a satisfactory account can be given of these, there is no reason why red should not be explained in a similar way, instead of being set aside by itself as due to some peculiar disposition.

The theory that the colors are complements causing each other must be given up for the reason that it, too, cannot consistently be carried through for all colors. At first thought it may seem reasonable to explain green as being the complement of the red, but the weakness of the explanation appears when we compare the brilliancy of the green with the brilliancy of the red, and note the time of excitation which precedes the appearance of green. Even allowing that the green-yellow of the following ring may result from the same cause, we are not able to account for the brilliant, luminous blue which appears in the fourth ring. The theory of irradiation has already been given up. Contrast must also be discarded as an ultimate cause, although (as has been shown) it plays its part in the phenomena.

One naturally looks to one's facts as reinforcing or making against some existing theory of visual sensation. Unsystematic work with the discs might easily lead to the conclusion that the results would furnish verification of the Helmholtz theory; but further work would inevitably lead one to abandon a three-color theory. In our own work it looked for some time as if there were only three colors present, even with the four-ringed discs. But the fact that the third ring (Fig. 1) changed so often to a blue-gray or stone-blue led us to believe that the excitation caused by it was of a nature different from that caused by the second ring, or concerned a different visual substance. The fact that when for any reason ring 3 grew lighter it grew yellower, led us then to believe that it was the amount of black that was obscuring the yellow: hence the series of discs was made which has already been discussed in IV § 3. When this difficulty was obviated, it was evident that the reaction to this ring was yellow. This fact was further borne out by the experiments with the colored backgrounds (IV § 9). We then turned to an examination of the four-color theories, and after a consideration of them finally selected Ebbinghaus's modification of Hering's theory as that which furnishes the most adequate, the most detailed and the most concrete explanation of the experimental results.[1]

This theory was chosen with an understanding of its uncer-

[1] Ebbinghaus, H.: Zeit. f. Psy. u. Phys. d. Sinnesorg., V, 1893, 145-238. This article gives more detail than the account in the *Grundzüge der Psychologie*, 1897, 169-263.

tainties, and of the criticisms which have been passed upon it.[1] Ebbinghaus himself accepts the Hering theory, with the reserve to which one is forced by our lack of knowledge of the physiological processes of the retina, but accepts it because it is at least typical of the processes which must be present. In the same spirit, then, in which Ebbinghaus accepts the theory of Hering, we here accept the theory of Ebbinghaus. It is a mode of representation of the facts which we have obtained. Thus we set to work with our eyes open, as it were, understanding our limitations.

According to the Ebbinghaus theory, normal color-vision is mediated by three substances that are sensitive to light. One of these, the white substance, is spread over the entire retina. It absorbs the light-rays of almost the entire visible spectrum, and this absorbed light serves to decompose it. The energy thus set free is in a form suitable for the excitation of nerves, and the result of this stimulation appears in consciousness as a sensation of brightness.

A second substance, which is found in the layer of rods and cones, and which does not extend over the entire retina, is identical with the visual-purple. It absorbs preferably the yellow rays. The decomposition-product formed by this absorption in its turn forms the visual-yellow. This visual-yellow absorbs the blue rays, forming a decomposition-product which gives rise to the visual-purple again.

A third substance, which is found in the cones and which thus covers a more limited area of the retina than either of the other substances, is called the red-green substance. Originally it is colored green and absorbs the red rays. The decomposition-product resulting from this absorption forms the red substance which absorbs green.

Thus in both chromatic substances there is a circular movement, a continual change of the one substance into the other. No substance is ever entirely exhausted. This color rhythm is always accompanied by the excitation of the white substance, by which energy is set free.

[1] Kœnig, A.: Sitzungsb. d. Akad. d. Wiss. zu Berlin, 1894, part II, 577-598, *Der menschliche Sehpurpur und seine Bedeutung für das Sehen.* Kœnig agrees with Ebbinghaus regarding the change of visual-purple into the visual-yellow which gives the sensation of blue (591). But he says that the still unknown visual substances which mediate the sensations of green and red (as well as the visual-yellow) are decomposed with more difficulty than the visual-purple (591). The results obtained from our discs disagree with this second statement.

Other important refences are: Kœnig, A.: Zeit. f. Psy. u. Phys. d. Sinnesorgane, IV, 1893-4, 241; von. Kries, J.: same Zeit., XIX, 1899, 175; von. Kries, J.: same Zeit., IX, 1895-6, 81; Hering and Hess: Pflüg. Arch. (Arch. für die ges. Phys.), LXXI, 1898, 105; Kuehne, W.: Hermann's Hd-bh. d. Phys., III, part III, chaps. 1 and 3.

Ebbinghaus differs from Hering in giving to all these changes, which are the immediate conditions of sensation, the name of dissimilation processes. He gives them all the same name because he believes that their modes of excitation are not essentially different.[1] Stimulation by one color excites all the visual-substances. Ebbinghaus objects to naming one part of the result of stimulation assimilation, and the other part dissimilation. Hence it follows that the excitation curves of complementary colors are not entirely antagonistic but partially coincide. Ebbinghaus believes that this simultaneity will explain the action of complements better than will Hering's theory that the one color blots out the other. These are the main points of divergence between the two theories.[2] Ebbinghaus attempts to bring the psychical facts into more specific relations to physiological substrates, and to give the colors a more definite temporal relation.

According to the Ebbinghaus theory, after the eye has been in a state of rest it is in a condition to have the sensation of yellow: *i. e.*, there is then a comparatively great amount of visual-purple, dissimilation of which gives rise the sensation of yellow.[3] The decomposition-product of visual-purple gives rise to the visual-yellow, by excitation of which there is produced the sensation of blue. Regeneration of the visual-yellow in turn gives a greater amount of visual-purple, which is again ready to be decomposed. Regeneration does not take place so rapidly as decomposition, and the rhythm proceeds more slowly as decomposition continues.

Ebbinghaus notes the discovery by Kuehne of the inertia of the visual-yellow,—that it often persists for hours before becoming colorless.[4] This means a heaping-up of the yellow substance, and it in turn reacts upon the visual-purple. If the visual-yellow is decomposed slowly, then the visual-purple is regenerated slowly because material is lacking. It cannot be entirely exhausted, for the visual-yellow is being spontaneously decomposed.

Kuehne experimented with the frog's retina, and found that ten minutes exposure to strong sun-light is necessary to bleach the visual-purple, and that regeneration requires from 1 to 2 hours. The rate of bleaching is much more rapid in warm-blooded animals,—sixty times more rapid than in the frog.[5]

[1] Ebbinghaus: *op. cit.*, 185, 195–6.

[2] Christine Ladd Franklin, at an earlier date (Proc. Internal Congress Exp. Psy., London, 1892), published the same criticisms of the Hering theory. Also in Mind, N. S. II, 1893, 473; Science, XXII, 1893, 135.

[3] Ebbinghaus: *op cit.*, 202.

[4] Kuehne, W.: Hermann's Hd-bh., III, 1, 278, 287; I, 432.

[5] Also in Schaefer's Text-book of Physiol.; II, 1900, 1045.

These facts, or at least facts analogous to them, accord with the phenomena of the discs. The yellow was apt to turn blue after short periods of observation, while the blue persisted practically unchanged during long periods.

This theory of Ebbinghaus's corresponds entirely with the results obtained from our discs. Upon rotation it is ring 3 (Fig. 1) which gives rise to the sensation of yellow; *i. e.*, there is a relatively *short* white-stimulation which is suddenly cut off by black-stimulation. It is ring 4 which gives rise to the sensation of blue; *i. e.*, there is a relatively *longer* white-stimulation which is suddenly cut off by black-stimulation. This must mean, then, that the duration of stimulation is sufficient for enough of the visual-purple to be dissimilated, which dissimilation-product forms visual-yellow, excitation of which gives rise to the sensation of blue. This fact may also give us some idea of the time required for generation of visual-yellow, over and above that already present during a condition of rest, which is sufficient to give rise to the sensation of blue. This theory is further borne out by the fact that if the eye is in a state of fatigue, so that in ring 3 the eye is scarcely renewed at all by the rest, the lines which should give rise to yellow pass over into blue. H. was especially liable to such fatigue. In disc 15 (all lines in sector 3) H. saw ring 1 as violet; in disc 19 H. saw all rings as rv, and to W. they were blue-gray, while to B., M., and O. they were yg. In disc 20, where the lines were longer, B., H., M., O. and W. saw all rings as bluish. The case is similar with regard to red and green. It is ring 1 (Fig. 1) which gives us the sensation of red; *i. e.*, there is a sudden excitation which is continued. It is ring 2 which gives us the sensation of green; *i. e.*, there is white-excitation which is suddenly cut off by black excitation, there is then another white-excitation which is again suddenly cut off. If the eye is fatigued, so that the passing of the lines gives insufficient time for regeneration, the green becomes mottled with red. With W., who almost never saw green, the *gray* almost invariably has spots of red "here and there."

All the facts of the disc correspond with the Hering theory. It is the dissimilation colors, the yellow and the red which appear first, and the assimilation colors, the blue and the green, which appear second.[1]

Thus, we postulate some substance, or a series of substances, to which belongs a definite temporal reaction to white light. Even if there are no substances which correspond exactly to

[1] The temporal series red, green, blue obtained with the disc is in agreement with the series obtained by Kunkel (Pfl. Arch., IX, 1874, 197) with *adequate* stimuli reduced to equal intensities.

the theory of Ebbinghaus, the theory which he has advanced may be said to be typical of what the true theory must express when the proper physiological substrates are discovered. We may even go a step further than Ebbinghaus and make the postulate that the dissimilation of red and green takes place before the dissimilation of yellow and blue. Thus we have the complete temporal series red, green, yellow, blue.

To summarize: color sensations which have definite temporal relations to each other may be produced by the rapid alternation of black and white sectors. The colors are further dependent upon the duration of stimulation, and the co-excitation of black and white. They are also dependent in less degree upon length and width of lines; upon their position within the sector; and, as are all other subjective states, upon bodily conditions, practice, fatigue, and attention. These conditions are necessary for the production of color itself; but after it is once present its quality may be changed by change in rotation of the disc, change in amount of light, and by addition of background color. All the phenomena find a satisfactory explanation in terms of a four-component color theory.

ERRATA.

P. 496 read:

II—5.	Red, 4.	Green, 3.	Yellow, 2.	Blue, 1 (yellow)
III—7.	Red, 4.	Green, 3 (yellow)	Yellow, 2 (yellow)	Blue, 1

P. 497 read:

X—1.	Red, 1 (green)	Green, 3 (red)	Blue, 2 (green)
XIII—2.	Red, 2		Blue, 3 (red)

P. 510, line 4 read:

Purkinje phenomenon with the light-adapted eye: see Hering, Arch. f. d. ges. Physiol., lx, 1895, 519.

P. 511. First line of Table, for VgBg read Vgyg.

A PRELIMINARY STUDY OF THE BEHAVIOR OF MENTAL IMAGES.

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Most of the treatises on the topic of imagery have been grounded on the isolation and classification of the material, and have possessed all the advantages and disadvantages of this method. The facts comprised in the term mental or associational type are a contribution of the very greatest importance. To determine the special sense channel in which a subject's mental processes tend to flow is now a recognized prerequisite to psychological work, since it gives a constant known quantity, so to speak, in the estimation of all results obtained from him. The chief criticism to which the method is liable is that its conclusions are based on mass results, hence too general and lacking in that concreteness which the subject of images can justifiably demand.

The present study[1] is an attempt to supplement the classificatory results by an examination of particular images, if not in their functional relations, at least *in situ*. It was our desire at first to make an exact register of the behavior of the image as regards the time intervals of clearness, indistinctness, disappearance, etc., and in this way obtain an index of its persistence in consciousness. We soon found it impossible, however, to make such a record, as the slightest attention given by the subject to the work of registration, even with the most delicate instruments, resulted in the immediate and permanent loss of the image. Actual trial proved the method not only impossible but also undesirable as the changes in the appearance of the image were found to depend upon a set of circumstances quite as important as the changes themselves and entirely too complex and variable to reduce to exactitude. So it was thought that the accumulation and comparison of introspective results, obtained under test conditions, would afford the best means of approaching the image in its actual relations. This, of course, required subjects who were exceptionally well trained in methods of introspection. As to type, one was strongly visual, another auditory-motor, and a third visual-motor, so that there

[1] This investigation was undertaken at the suggestion of Dr. Sanford, and part of the work was carried on with his assistance.

was sufficient diversity to keep the conclusions from the error of being based on one-sided results. All of them had had several years of training in psychological work, and were used only after trial had demonstrated their expertness in introspection. Incidentally, it is surprising how many supposedly well trained experimentalists are found deficient in this requirement, and the insistence by Professor Titchener upon the fact that the experiment is only an arrangement of conditions to assist the introspection, may be considered most timely.

The method was to ascertain as nearly as possible the exact behavior of the image during a certain interval of time, which after trial was fixed at ten seconds.

Visual Images.

Visual images are by far the clearest and most independent, and in consequence, have offered the most fruitful field for the investigation of the general subject. For the study of related problems, like those of memory and association, that material would naturally be chosen which was least involved with other factors, and which would show in the most direct way the result to be attained. The consequence is that images from other sense departments have been largely ignored in the literature, and relatively too much prominence given to those of a visual nature. Fechner's description[1] of his own visual images is given solely for the purpose of distinguishing them from after images, but is, notwithstanding, the best account of their characteristics yet presented. The chief distinctions, he tells us, between after images, on the one hand, and memory and fancy images, on the other, are that the former appear only with a feeling of receptivity, in connection with a certain sense impression, and independently of voluntary effort and association of ideas; and depart, also, relatively to the immediately preceding sense impression, and independently of voluntary effort. Memory and fancy images arise with a feeling of greater or less spontaneity, a longer time after the preceding sense impression, partly involuntarily through the association of ideas, partly voluntarily, and can be varied and banished in the same way. He describes his memory and fancy images further as seeming to lack corporeality, as washed out and indefinite. He cannot obtain clear sharp boundaries and can produce only the most familiar memory images of objects that are daily before his eyes. He cannot hold the memory image more than a short while. It must be renewed if observed longer. If he tries repeatedly to call it up, the attention or production activity becomes blunted. This is not at all a blunting of recall (mem-

[1] Elemente der Psychophysik, II, p. 469 ff; 1889.

ory activity), since he is not hindered from calling up another memory image just as clear, and when the attention goes back to the first image, it can be produced with original clearness. This holds of closely related images, as two figures in the same photograph, or two portraits in the same room. If these are used too continuously, the attention blunts for both, but can turn to a third and back again in the same way. In no case can he place objects in the memory field in other relations to each other than as corresponding to the forms of actual observation, and his fancy cannot operate with its creations outside these limits. Thus he cannot represent a man full face and in profile at the same time. Another result is that he can succeed more easily in arousing memory images with open than with closed eyes. The field is more limited but still relatively clearer. To do this he must entirely withdraw the attention from without, and can succeed better when the eyes are turned toward the floor. It is as if with complete closing of the eyes, the lightstuff, of which the images are woven, is lacking; as if the dark field is more disturbing for its perception than the soft daylight. Memory images, unlike after images, are possessed of perspective, and can be made to appear in any direction desired. He can pass from one memory image to another quickly, almost simultaneously, with a feeling of continuity; can also pass from after image to memory image quickly, but the continuity is broken. The attention must be abstracted from the after image in order to get the memory image. The only reference he makes to the relation of images in the different sense departments is that when we pass from one to the other, there is a definite, not to be described but easily reproduced, *feeling* of the changed direction, which we can liken to a differently localized tension, as from eye to ear.

Reference has been made to Fechner's work at length because it is the nearest approach in the literature to the object of the present study. Galton's chapter on "Mental Imagery"[1] is chiefly of a statistical and descriptive nature. He considers the question of visualization from the point of view of its prevalence, and finds it generally deficient with men of science, strong with artists, vivid with children and primitive peoples, and varying somewhat with nationality. The work, while of the greatest value in a general way, can hardly be relied upon in its discussion of particular points, and shows throughout the deficiency of not having subjected its material to exact experimental conditions.

Among later works may be mentioned those of Lay[2] and

[1] Inquiries into Human Faculty.
[2] Psych. Rev. Mon. Sup. VII: Mental Imagery.

Bentley.[1] The former is almost entirely a study of types, based upon results obtained from students, artists and himself. The latter is an investigation of the visual memory image with reference to its qualitative fidelity and the effect of varying intervals of time upon it. The materials considered are brightnesses and colors, and the work is of great value from the standpoint of both method and results. It suffers only from the exceedingly limited range of its experimentation. There is included a most suggestive section on the genetic function of the memory image.

We have used the terms *mental image* and *memory image* as referring to the same set of phenomena, and perhaps it is necessary to justify this procedure by explaining in what sense they are interchangeable. Memory image has come to mean, specifically, one in which is reproduced with more or less completeness the original observation, with all the factors necessary to make it determinate. It is a process in which recall and recognition play an important part. The meaning of mental image is not very definitely fixed by usage, but with some the term characterizes that large group of images whose location in space and time has been lost. The question is chiefly one of familiarity. We do not call the image aroused by the word *horse* a memory image, because horses have been seen under so many sets of circumstances that no one stands out in particular. It is valuable for some purposes to preserve this distinction, but it really rests on a superficial analysis. The word *horse* is, in ordinary usage, little more than a word, and if any image is aroused, it is in most cases general, shadowy, symbolic and of only an instant's duration. If it is required that a definite image be produced and held when the word is called, it will be found that a very definite associative complex will come up in connection with it. This is either a particular situation from past experience or a composite of such situations. If the name of a certain building with which the subject is familiar, is called, the resulting memory image has reference, not necessarily to a particular occasion of observation, but to many such occasions, and is, really, in its turn, a composite. So the mental image is hardly one in which particular reference is lost, but in which the possibility of particular reference is manifold. So under the conditions of our experiments, which necessitated in every case the production of a definite image, it would serve no purpose to keep the distinction rigid.

In the following tests, with the exception of the card series, drawn figures were used instead of call words. The purpose in this was to keep the associative complex as much as possible

[1] *Am. J. Psych.*, XI, 1: The Memory Image.

under control. The subject was permitted to look at the figure for some time before the "ready" signal was given, at which he closed his eyes. Five seconds were allowed to elapse between the "ready" and the "now" which marked the beginning of the ten seconds interval, in order that the after image and the memory after image might pass away. A second "now" was used to close the interval, and the introspection was taken as quickly as possible.

(1) *Small black square on white card.*

St. Could not get it in several trials. Some figure would form around it and when he tried to drive it away whole thing would go.

K. Was able to see the black square; seemed to be hollowed out on two of the sides. Then movement of the attention from the square to the four corners of the card. Gray lines came in as diagonals and gave the whole card the appearance of a pyramid truncated at the square. Then came a blank period of about two seconds. Image was vague during remainder of period and only came out in flashes.

(2) *Black square in larger square.*

St. Could get only one side in. Others seemed to be there but not distinct. Spot quite clear.

K. Lines of outer square came first, with blotches or knobs in the corners; lasted about three seconds; very bright and distinct; central square entirely absent except for the vague feel of something there. Then went to square in center and imaged figure as a whole. Not distorted except for the corner spots. Did not notice outline of card.

(3) *Black and two surrounding squares.*

K. Saw outside square first; light yellowish; corners prominent again; lasted about a second. Then started on next square and got the two together. Middle spot still left out; did not appear distinct at any time. Figure did not hang together as one image. After about five seconds whole thing very vague. Corner knobs came on only the outside square; otherwise form not distorted.

(4) *Squares with diagonals added.*

St. Squares much more prominent than spot; two diagonals most distinct. Time of distinctness much greater than time of indistinctness; change very gradual; did not disappear at any time.

K. Whole thing vague. Started on outside lines; vague notion of lines inside; no perspective. Then got feeling of motion in figure waving back and forth. Then black square in center came out very clear. Then vague perspective as looking into hollow. Lines still vague and outlines of hollow not clear but black spot remained so.

The above series seems to warrant these suggestions and conclusions.

(1) It is a matter of the greatest difficulty to get and hold a very simple image like that of a small black square. Neither subject could get it alone in repeated trials. An easy form of the experiment is to place a white dot on a large blackboard, and after looking at it, close the eyes and try to hold it for several seconds. It will be found impossible in most cases.

(2) This leads us to conclude that a certain degree of com-

plexity is necessary in order to make an image continuous. This has an illustration in the second test where subject St could get only one side of the surrounding square, but this was sufficient to make the spot quite clear. A result that was entirely unexpected was the tendency of both subjects in the first test to supplement the lack of complexity in the figure by adding a subjectively created means of holding it. With St, this consisted of surrounding lines, and with K, of diagonals leading from the square to the four corners of the card, and throwing the whole into the perspective of a pyramid truncated at the square. Another interesting fact came out in the blackboard experiment. An image of the whole board would first be obtained, and immediately afterward the image of the dot would flash out clearly for an instant. While this was happening, however, the outline of the board would disappear completely. It would seem as if the image itself could produce a memory after image of position, which would persist for a moment after the disappearance of the image. Examination of any of our complex memory images will show that what seems to be an entire picture is really a matter of successive parts, a residue of position running from each into the next so as to give the feeling that they are presented simultaneously.

(3) The tendency to emphasize angles, as seen in the knobs which K placed at the corner of the square, and diagonals which with St took precedence of the rest of the figure, will be discussed later under the schematism of the image.

(4) The last two tests are remarkable for the diversity of results. When the figure was made more complex by the addition of another square, neither subject could hold the image complete but broke it into parts. K says definitely that it did not hang together as one figure. With St, when the diagonals were added, it became very difficult to get the spot. The opposite was true of K who threw the whole figure into pyramid perspective in which the lines were very vague but the spot very clear. It seems that here we have an indication of the limits of complexity in a plane figure which it is desired to hold as one image. If true, the range from minimum to maximum complexity is a very narrow one. It is, at any rate, evident from these tests that the clearest and most persistent images are those in which the spot stands in close relation to only a line or an angle. The probable difference between this and greater complexity is that the latter requires more time for the play of attention, and in this way the continuity in the perception is broken. The sense of perceptive which K had in the last test seems to be a means of subsuming a complex setting into a simpler one.

(1) *Semicircle.*

St. Able to get it easily, but when tried to hold without losing, brought on a sort of quivering. Direction and size as shown. Clear about two-thirds of time. No tendency to eye movement noticed.

K. Started on left-hand end of image and went around circumference. Figure distorted by bulging out in left quadrant. Slight stop at that point then rest of the way around. Saw the figure complete after about two seconds; then lost; afterward returned as whole for an instant. Did not notice eye movement.

(2) *Circle.*

St. More fluctuation than in semi-circle between distinctness and indistinctness; much harder to hold. Not all parts clear at same time. When made circumference object of attention, decided tendency to move eyes around. If on center, no tendency to eye movement, but circumference not clear in all parts. Attention moves either across or around. Some tendency to distort by making vertical diameter longer. Fluctuations about a second long.

K. Noticed center point first; then went to left and around. Seemed to get the circumference in pulses. Then got all parts equally distinct but lost center. Figure distorted by becoming smaller and larger. Several blank spells.

(3) *Circle with crossed diameters.*

St. Upper left and lower right segments only ones that came out, so that figure took hour-glass form. No tendency to eye movement.

K. Upper right and lower left sectors came out; really saw spaces without noticing lines. Other two were added on but looked darker. Then let rest go and tried to see circumference; got upper left segment. Then finally got circle complete with indistinct contents; lost idea of being cut up in parts.

(1) The first result of importance in this series is that curved lines are harder to hold than straight ones. The semicircle could be held complete, though only for a short time, which is undoubtedly due to the straight line forming the diameter. The circle was much more subject to fluctuations, and only a part could be held at one time. The result obtained from St in the circle test is typical of the way in which curved lines are imaged. If attention is given to the center in order to get the whole figure, the circumference becomes indistinct. If the circumference is brought out clearly, it comes in sections following the movement of the eyes which is very perceptible. This latter fact gives a clue to the difficulty, in holding a circle as compared with a straight line. The eyes seem to move easily in following a line even of considerable length, and with much greater difficulty in following a curved line. If the movement is not exact and well-controlled, the result is a distortion of the figure, as in all of K's images of circles. It may be that this difference in the ease of eye movement is carried over into a difference of ease in holding the image.

(2) In the final test, the result is the same with both subjects. The crossed diameters are so prominent in the image that

they shut out the circumference almost entirely by arresting the necessary eye movement. The greater clearness of opposite rather than adjacent spaces, is a fact that comes out in all experiments involving crossed lines. Both this and the joining of the ends by opposite segments is probably due to the attempt to follow out both lines at the same time. This is certainly true with the writer, who finds in addition, that the angle subtended by these segments constantly tends to grow smaller and the lines to run together.

(1) *Blank playing cards.*

St. First was of indefinite white background. Changed into ace of spades; not very distinct. Card was out in front, against gray background; position oblique.

Sr. White background; white card cut off from background by black lines. Black lines became indistinct about three times. By end of period had gone completely.

(2) *Ace of hearts.*

St. White background back of ace and some distance from it. Other images tried to crowd in. Fairly clear ace, a little larger than real. Card some clearer than blank.

Sr. Got card in oblique position on wall; heart in middle. First, a confused red, then changed to ace of spades, then came out clear red. The spade was small and ordinary size, not large and elaborate, and pointed down like the heart. Clear at end of period.

(3) *King of hearts.*

St. Fairly distinct, but kept oscillating. No outline to card; only heart and king visible. King seemed pretty clear; color same as real.

Sr. Confused at first. Card straight: king double with sceptre, might have been the knave, not the queen. No heart visible. Figure darkened and grew confused toward the end.

(4) *Straight flush from ace of hearts.*

St. Could see about two at a time in row: rest mere outline of hand. Passed down the row in this way.

Sr. After a time of confusion saw them spread out with ace at left and others in order. Ace was clear and remained so all through. Picture cards confused and could not be distinguished, Nothing definite about the others; shaded off into darkness; even the number could not certainly be fixed. Still trying to get the other cards, starting from ace which remained clear, when time ended. Colors in picture cards fairly clear.

The facts shown in the first two tests are the production of the blank card by cutting off a part of the gray background with black lines, and the tendency of closely related images to crowd in. This is one of the very few instances in these experiments where an antagonism of images was apparent, and here it is along a natural path of association. The third test shows that where a figure of great complexity stands in conjunction with another of little complexity, the latter is liable to be entirely neglected. With St, the outline of the card was lost,

and with Sr, the heart did not come in. The image of the straight flush affords a good study in the relation of extent and detail. St could hold the outline of the hand and pass along it seeing two cards at the time. Sr could hold the outline and ace clearly, but the rest remained confused.

(1) *Letter A.*

St. Had some trouble in getting it. Hard to hold. Could not get natural size, seemed much larger. White spaces clearer than lines. Black was grayish. Was not defined clearly as letter, openings were too large.

St. More nearly natural size. Fluctuation in clearness very rapid; caught himself moving head in sort of rhythm corresponding to clearness. Did not repeat letter verbally. Noticed no tendency to run to other images during fall in clearness.

K. At first quite clear cut image as it is with white center left out; lasted about two seconds; broken by negative after image. Then again more distinct of letter with white space; better defined than before; lasted through.

(2) *Letter A in "ATE."*

St. Succeeded in getting A more prominent than TE. TE kept coming in, and oscillated much in intensity. Attention ran from A to TE then back; seemed rhythmic. Caught self repeating A-T-E over and over.

St. Much the same as before. Noticed in addition movement of eyes when TE came. Tendency to repeat letters very distinct. Dropped into indistinctness but for no appreciable time.

K. First a somewhat indistinct image of letter A; then T a little more distinct; E rather vague. Then back to A and got a very clear image of it. Articulatory of T; E remained indistinct. Then tried to get whole word visually; A distinct and other not. At last dropped into mere articulation of A-T-E.

(3) *Letter A in "RELATE."*

St. Conspicuous thing was inability to get A alone for any length of time. RE was indistinct for awhile then was most distinct. L did not appear at all. A did not disappear completely at any time. Tendency to run over letters but not to speak word. After other letters came up distinctly, attention always ran back to A.

K. Very vague visual of space that word takes, letters indistinct. Started to articulate; word broken in this way into two parts REL-ATE. Visual came again and followed the division. Got R very distinctly, other two vaguely; same when went to last part. Visual on whole less distinct than motor.

These letter tests are in some respects the most interesting of the visual series, because they show the visual in connection with articulatory-motor elements, a combination rendered unavoidable by long association.

(1) The single letter appeared as a purely visual image, without tendency to articulate, hard to get and hold, and much subject to fluctuation and distortion.

(2) In the second test, St found the attention running from A which remained prominent to TE, and back again in the

rhythm set by the articulatory process. In the final test, K broke the word into two parts by articulation and then visualized it as broken, with the first letter in each part more prominent than the others. We have here a clear case of the visual following upon and being determined by the articulatory.

(3) It is to be noticed further that the A becomes clearer and can be held with less difficulty when articulated and placed in conjunction with the other letters. This latter process of reinforcement is probably the same as was found in the square series, where a slight complexity was necessary to give the attention play and also hold it within certain limits. The repeated articulation makes a direct and regular path back to the letter.

EXTENT AND SCHEMATISM OF THE INNER VISUAL FIELD.

The apparatus for experimenting upon this subject consisted of a black cardboard, two feet square, on which were pasted in regular arrangement five rows of five red spots, each an inch and a half in diameter. The subjects were not placed under time conditions, but were allowed to look at the board whenever they wished, and after closing the eyes, to continue as long as the image could be held easily. The introspection, as usual, was taken in full immediately. There is complete uniformity of results with all the subjects tested.

(1) When the effort is made to get an image of the whole figure, two indistinct rows come out, one on top, the other on the side. These consist merely of dark broad lines in which the individual spots are not defined. The rest of the board is confused.

(2) The easiest and most persistent arrangement of the whole board is that of two squares, an inner and outer, with the center left out. This again consists merely of the dark lines which sometimes look like indefinite beaded lines. If the attempt is made to bring out any particular spot, the squares break up and disappear.

(3) If attention is given to the central spot, isolated from the rest, it is hard to get, comes out only in flashes, and does not keep its position, but tends to stand out from the board or run over it.

(4) If the top row is taken and followed across, the spots can be brought out successively but only momentarily. The end ones come out most clearly and remain longest, the inner ones darken and are harder to get. The row tends after a time to go into a jumble, but can be rearranged by stopping and catching the end spots. Order is kept by counting. Dark lines run down from each spot to represent the vertical rows.

(5) The maximum number of spots that can be held clearly

at one time is five. These arrange themselves in certain geometrical figures, as follows: (a) Four corner spots of outer square with vague center in the arrangement of diagonals. (b) Center and middle outside ones in the arrangement of horizontal and vertical crossed lines. (c) Center and corners of inner square. (d) Center and middle ones of inner square.

Two of the facts noted suggest a resemblance of the inner field to the range of attention with minimum time of perception. These are the geometrical arrangement of five spots, and the prominence of the ends when a row is taken. There is, however, an important difference in the matter of extent, in that the attention during its single pulse does not select the number perceived from a larger number. Like minimum external perception, again, a basis is laid in its one act for the perception of more complex images. The most important factor, probably, in the constitution of the inner visual field, is the dropping of certain parts into obscurity, without losing them as a setting for the parts that remain distinct. Introspection fails to disclose fully just what takes place. There is a vague "feeling of something there," together with a certainty of what it is, and of the ability to recover it if wanted. It is probable that most of the setting can reduce itself to a highly abstract, even geometrical, schema of directions and positions. When attention was given to the red spot in a corner of the board, it could be held firmly as to position by reason of the right angle formed by the edges, so that the appearance of the rest of the card could be easily studied. For one subject, there were two broad lines leading off at right angles from the spot held, representing the two outside rows of spots, while all the remaining spots formed an undifferentiated mass, characterized only by a slightly brighter illumination. For another subject, a better visualizer, the outside lines leading to the spot were clear, and also the two sides of the inner square parallel to these, the broad gray lines being the nearest approach to distinctness.

Binet gives an interesting discussion[1] of the visual memory of chess players, and their visualization during blindfold games. One of the questions which he addressed to the players concerned the extent of the image: "Do you represent to yourself the chess board and its pieces all together simultaneously, or only by parts which appear to you in a successive manner?" A single player, Tarrasch, affirms that he visualizes the board entire, and that that total visualization is necessary. But when he adds that he represents a small board in order that the mental regard may be able to pass more easily from

[1] Psychologie des Grands Calculateurs, 1894. p. 28 ff.

one space to another, it is very evident says Binet, that his visualization is successive. Another player, Schallop, says, "There are occasions when I see the board entire, but there are also others when I see clearly only that part of the board on which the combat is actually going on." "That last part of the response," says Binet, "states the opinion of the majority of the players. It is a rule, one may say, that players represent only a part of the board."

In a chapter on concrete and abstract visual memory,[1] there is presented an examination of the kind of image held in blindfold play. With some, he found visualization almost entirely lacking, the play taking the form of a mathematical calculation. With others who were in the habit of visualizing the board and pieces, all unnecessary details were dropped out and the image made as abstract as possible. One did not even distinguish the pieces except by a sense of their value. Generally, a detailed visualization of the board seemed to mark the amateur and was never characteristic of a proficient practiced player.

Motor and Motion Images.

The motor element in mental imagery was first adequately emphasized by Stricker, in two treatises. In the former,[2] he sets forth in detail observations made on himself relative to the various elements in the word, and deals especially with the fact of initiated but suppressed articulation in his word thinking. In the second,[3] he carries his theory of motor function much further and makes it the fundamental element in both perception and memory of every kind of movement, and the basis of a doctrine of causality. A quotation from the latter work will illustrate his point of view, and also present his contribution to the motor side of mental imagery.

"My recollections of the movements of all lifeless objects are for the most part knitted with feelings in the eye muscles. If I wish to represent to myself the flight of clouds, I must connect with the image of the clouds, the feeling, as if the eyes would follow them. If I try to suppress this feeling, immediately the idea of the motion stops, and the clouds appear as if bound fast. Just as with the image of the clouds, so it is with the memory of the flight of birds, of rising smoke, of the passing vehicle."[4] So Stricker found with the images of all moving objects, as the railroad train, wheels and other rotating objects, and even the hypothetical motions of molecules and atoms. In other chapters, he treats the muscle

[1] p. 284 ff.
[2] Studien über die Sprachvorstellungen, 1880.
[3] Studien über die Bewegungsvorstellungen, 1882.
[4] p. 17.

feelings which accompany the perception and representation of movements of living objects and of parts of his own body. Other writers on the motor side of mental imagery have limited themselves entirely, so far as could be ascertained, to the articulatory impulses in word thinking.

The experience of the writer coincides exactly with that of Stricker, so far as eye movements are concerned, and so does that of two of the subjects examined. A few tests are presented in the following.

(1) *Heavy line in long parallelogram to be seen moving.*

St. Had some trouble in starting it; sort of mass movement not clearly outlined. Moved rhythmically with eye movement which was very distinct. Continuous.

K. Right end was normal size, part to left of spot was smaller. Then spot took up position at corresponding place on other end, then back; repeated three or four times. Lines were very vague. Left end distorted further by becoming tube, this did not extend to rest of it. No eye movement noticed.

(2) *Figure of pendulum ready to swing.*

St. Eye movement clear. Seemed to feel a distinct accent on start of swing.

K. Felt when saw it that it would be impossible to avoid having it move. First part clear was bob and line which seemed decidedly behind it; then filled in rest of pendulum. Did not move as was expected but seemed held there. At last got it to the other side but only by going to the suspension point and coming down. Moved it back to its original position in the same way. Had queer feeling when saw it hanging there and not going.

(3) *Circle with ball to move around circumference.*

St. Felt eye movement distinctly. Image came up readily but somewhat distorted. Ball moved around about every two seconds. Remained fairly distinct; circle clear where ball was.

K. Imaged clearly about one-fourth of circumference on each side. Then clear image of ball and completed the circle. Came back to ball and it went up to left a little; circle bulged at that point and ball stopped; whole circle fairly distinct. Then vague spell of about one second before call.

Sd. ("Swinging pendulum" called.) Got large pendulum in motion but not clearly in motion at all points; more pulled off to left. Seen as clearly as in actuality. Tendency strong to swing head in time. Half way through attention was caught by retinal light, so lost pendulum but still kept time to it; behaved as if knew pendulum was swinging behind rose colored curtain.

The figures were drawn so as to show clearly the part to be seen moving and also the course of the movement, and the subject was instructed beforehand that the movement was to be produced in the image. The results, while somewhat diverse, bear clearly upon the same point, the importance of eye movements for motion images. With St, the feeling in the eye muscles was clear and continuous in all the trials. With K, no eye movement was perceptible, but he was also unable to

get any movement in the images. Another difference between the two subjects suggests a relation between the motor and visual constituents of the image. St found in the first test that while the movement was clear and regular, the outlines of the figure were more or less indistinct and describes it as a kind of mass movement. He has nothing to say about the visual image in the second test, and in the third speaks of the circle as clear only where the ball happened to be in the course of its movement. The record for K shows primarily the clearness and profusion of his visualization, and again that every attempt to produce a movement resulted in a mere distortion of the figure. This would seem to indicate that the inner visual field must be constricted, and the play of attention over the parts, necessary in holding a figure of any complexity, be eliminated in order to produce a motion image. In nearly all cases the play of attention is accompanied by slight eye movements which would, of course, conflict with the movement necessary to produce the motion.

Motion images may also depend upon the activity of other parts of the body with which they have become closely associated by habit. When the writer sits by his window rocking, the vertical stick in the sash frame makes a dark line moving back and forth on the gray background of the wall opposite. If the rocking is stopped and the attempt made to image the motion with eyes closed, it is found to be impossible however much eye movement is used. When the rocking is resumed, eyes still closed, it is impossible to image the line other than as moving rhythmically with the movement of the chair.

It is admittedly a matter of the greatest difficulty, in the present state of knowledge, to estimate the extent to which motor functions influence other conscious factors. Even the study of completed action, as the counterpart of the idea, brings up problems of bewildering complexity, and the consideration of impulses, vague tendencies to movement, residual influences of past actions, etc., falls within the region of the almost entirely unknown. As to the significance of these processes, however, there can be little doubt. The image, on account of its exceedingly fleeting nature, may be taken as an index sufficiently delicate to measure the influence of some of these factors, when it can be found both in and out of connection with them. Galton describes the results obtained by the method of a certain teacher of drawing. "He trained his pupils with extraordinary success, beginning with the simplest figures. They were made to study the models thoroughly before they tried to draw them from memory. One favorite expedient was to associate the sight memory with the muscular memory, by making his pupils follow at a distance the outlines of the figures with a

pencil held in their hands. After three or four months practice, their visual memory became greatly strengthened. They had no difficulty in summoning images at will, in holding them steady, and in drawing them. Their copies were executed with marvellous fidelity, as attested by a commission of the Institute, appointed in 1852, to inquire into the matter, of which the eminent painter, Horace Vernet, was a member." He also cites the case of a young Indian who was seen "tracing the outline of a print from the *Illustrated News* very carefully with the point of his knife. The reason he gave for this odd manœuver was that he would remember the better how to carve it when he returned home."[1] The following is clearly a case of the same kind.

In the course of the experiments with words and letters, the writer noticed the extreme difficulty he encountered in holding a printed letter or word as compared with those he had written. When the printed letter was visualized, it would come out in a flash and disappear immediately. The parts were distinct and normal during the instant but if held tended strongly to become distorted. The letter always seemed unfamiliar, and there was the repeated experience of giving great effort to the development of small details in order to complete the image. When the printed word was visualized, the letters were always indefinite and schematic, and seemed merely to follow in the trail of the more prominent articulatory process. Words of more than five letters required not less than two distinct acts of visualization which were lacking in any kind of continuity.

On the other hand, it was quite easy to obtain a clearly outlined and fairly continuous image of the letter or word as customarily written. In the case of the letter, the attention played over the image, bringing out one part after another in the order and same time rate, and with the same continuity as in the writing process. In the same way words could be visualized with great distinctness, and if not too long, held with some facility without the help of articulation. If the latter process was allowed to come in, whole lines could be run over easily and continuously, each word being given its appropriate place. The images were entirely, so far as introspection could ascertain, of a visual nature, and not accompanied by the slightest tendency to reproduce the writing movement.

A possible explanation of these facts is that tracing the figures merely gives greater familiarity by bringing all of the details to attention, and fixing a certain association series. Or, again, there may be a persistent motor tendency which directly reinforces the visual imagery. The two explanations may not

[1] Inquiries into Human Faculty, p. 105-6.

be so very far apart, because of the known motor element in attention, and the probable motor basis for continuity in association. The importance of rhythm will be treated in another connection.

Auditory Images.

No department of psychological literature contains conclusions more divergent and contradictory than that dealing with auditory images. This is apparently due to two facts. First, the observations recorded are almost purely of an individual nature, and seldom made under strict conditions of experiment and analysis. Again, the investigations have been limited almost entirely to word thinking, a choice of materials that must be considered peculiarly unfortunate, because both association and apperception have established in the word an almost unanalyzable fusion of elements. The consequence is that when an investigator finds the motor element predominating or deficient in his word thinking, he puts this forward as indicating the absence or presence of auditory images. Thus Stricker[1] and Dodge[2] find the sound of the word entirely lacking, and in its place merely a movement of the articulatory organs. Egger,[3] on the other hand, finds the sound of the word predominating, and concludes that the auditory image is independent of motor factors. There is no intention here to discredit these important investigations, but merely to ask the question if theseprocesses would repeat themselves in the representation of sounds not so inextricably woven into an established complex of relations. The question is, of course, too extensive to demand full consideration in studies whose primary purpose is the investigation of words, or even one of this kind. The peculiar value of Baldwin's contribution[4] is that he points out the fact that the kind of word thinking has a deeper basis than a general fixed tendency, and depends in large measure upon associations incident to training, which may vary considerably for different departments within the same individual.

The method in our experiments, a few of which are presented here, was to give the "ready" signal two seconds before, and the call word at the beginning of the ten seconds interval.

(1) *Tuning fork.*

St. Felt tension in tongue but could not really get sound. Had sort of humming located in mouth, fairly continuous. No visual image of fork. No kind of outside setting.

K. Got sound image a little preceding visual. Visualized fork on

[1] Studien über die Sprachvorstellungen, 1880.
[2] Die Motorischen Wortvorstellungen, 1896.
[3] La parole interieure, 1881.
[4] Internal Speech and Song; Phil. Rev., II, p. 385.

box. Double image continued through. Did not notice movement of throat muscles. No change in breathing noticed.

Sd. Doubted if he got genuine auditory image. Visualized fork in laboratory room. Repeated "pong" a number of times. Attempt to make sound image kept up to end of period. Probably no external sounds entered in as they failed to fit. Fork noticed was about an octave below middle C.

(2) *Two tuning forks with beats.*

St. Visual image of two forks. Oscillation of attention between forks that really seemed external and the humming in head. Beats were only rhythm put in by emphasis in humming. Visual image had no setting, seemed just in front in air. It fluctuated considerably.

K. Visual image not so prominent. Got sound first, then visualized two forks vaguely. Beat very distinct; tendency to follow it with hand, also in vocal organs. Tendency to visualize beat as motion in air between forks with vague waves coinciding and opposing. Had been somewhat in habit of doing this.

Sd. Got it pretty well and held clearly. Visualization of forks on boxes, but not so distinct as before. Less vocal than before. First mostly auditory and toward end almost entirely motor. Beats not perfectly regular, two or three per second. Persistence seemed to depend on its being motor.

(3) *Slowly dripping water.*

St. No visual imagery. Felt distinct movement in throat. Rhythm intervals about a second long. Word "drop" was repeated with the rhythm.

K. First visual image of faucet and rather vaguely of basin. Sound image very distinct. Did not follow drop down but could feel it when it struck; some motor element in this. Eye followed waves on surface of basin. Did not notice any movement in throat. Drops came every second or so.

Sd. First indistinct visualization of water dripping. Then became very definite with visualization of leaky radiator (memory). Tendency to imitate by use of word "drip" at regular intervals. Rather more motor than auditory on the whole; continuous. At end all had degenerated into mere use of word.

(4) *Quickly dripping water.*

St. Seemed as if in room and sound outside, but no visual image of room or water. Sound was not "drop," realized that it was too slow; was a kind of "ta" repeated rapidly. Chief part of the whole complex was movement in throat. Continuous on account of rhythm.

K. At first a clear visual image of string of drops close together with very vague visual of faucet and basin. Then sound image as before only more rapid. Sound did not fit the string of drops so did not hold it. Fluctuation between sound and visual image trying to get fit. Slight eye movement in following the drops down. Got sound image when reached bottom of string.

Sd. Partial visualization at first. Obscure "drip, drip" said rapidly. A few associated images with it. Too much engaged in introspection and image disappeared.

(5) *Waterfall.*

St. Visual image of waterfall and water falling over. Movement of throat muscles more in background and deeper. Some holding of

breath. Both auditory and visual pretty continuous. No tendency to use roar of street car passing outside.

K. Visual (memory) of waterfall. Motor element in following water down. Then got sound down below. At last got whole thing together—fall, basin, spray and sound. Auditory fairly constant.

Sd. Visual image more prominent than auditory. Something of auditory nature but should hesitate to call it an image. At one stage tendency to fit sound of wind outside to waterfall but given up. Whole thing weak. No motor side. Last two seconds nothing but more or less distinct memory images.

(6) *Ticking of watch.*

St. Felt clear movement of muscles. Began too slow for watch, more like clock, so forced a more rapid movement. Then came visual image of watch just out in front. Repeated word "tick." Continuous.

K. Sound image first, then visual of operator's watch. Visual constant, sound not. Motor element in sound in marking rhythm; also used word "tick." In last part was following out details of visual.

Sd. Some tendency to imitate but less than with water. One instant tried to get operator's watch, then tried to get ticking in purely auditory way. It came almost pure but slipped away very quickly each time. Came three or four times. No definite picture of watch. Ticking very rapid.

(7) *Whistling of wind.*

St. Seemed in roof of mouth. No tendency to use outside sounds. Sound was of whistling around corner of house but no visualization of house.

K. Sound preceded vague visual, localized just outside. Visualized wind as streaks in the air going around eaves; followed motion with eye. Strong wheezy whistle. No throat movement.

Sr. Something of a memory image. Fairly easy to get but hard to hold. Came and went several times; toward last seemed to come in quick gusts. Attended by visualization of corner of house and distinct tension in throat.

(1) The fact of primary importance ascertained from this series is that we are dealing with a vastly more complicated set of conditions than in any of the experiments previously considered. Images of a visual character are possessed of a certain degree of independence, and the conditions of their maintenance are chiefly, for introspection at least, to be found within themselves. Again, motor images when taken in isolation, merely require a partial repetition of the original movement or impulse to that movement. But apparently in the case of auditory images, the conditions both of obtaining and holding them have to be brought in from outside. In other words, the study of auditory images is chiefly one of association, both of ideas and sense elements. The auditory element seems to be partially distinguishable from the associative complex focused upon it, as shown in those cases where the situation was held continuously and the sound came and went. In other cases, the situation was all that could be obtained, and a word was used to fill the

place of the image, as with the dripping of water and ticking of watch.

(2) The most important incentive to the production of sound images is, without doubt, movement of the organs of articulation, especially the throat muscles. The series of tensions and positions used in actually producing the sound stand so closely connected with the image that the latter often seems to come directly from them and to be heard only inside. If they are lacking, on the other hand, in many cases mental audition is impossible. When, for example, the writer wishes to recall a phrase of music that he has heard, it can be done only after the tensions fixing the tone relations are definitely under control, which sometimes requires several days of trial. Another motor element, upon which the production of sound images depends, is rhythm. It is a kind of solid skeleton, so to speak, which supports the soft tissues. It is doubtful if a continuous, unvarying sound image can exist at all. On the other hand, one that comes at regular intervals can be produced very easily.

(3) An interesting distinction comes out in the series between two of the subjects. St really has much better auditory images than K, and is strongly motor, while K is strongly visual. When St in his introspection, analyzed his associative complexes and found the motor elements so predominating, he became very doubtful if he got any sound image at all. K, who visualized to the extent of seeing the sound waves between the forks, and the streaks of wind around the eaves, and felt no tension in the throat, was quite sure that he got distinct sound images. This raises the question as to the comparative sufficiency of the two kinds of complexes. The visualist probably proceeds more from the standpoint of the object and the enumeration of qualities. When the object stands out complete except for the sound, and the whole situation is arranged so as to point to it, it may seem present as a matter of course whether it actually appears or not, and may seem as clearly distinguishable as any of the other qualities. It is similar to the case of filling in the blind spot in the field of vision. On the other hand, the subject who visualizes little, and in whom motor elements predominate, must proceed primarily from the standpoint of these elements, and when he attempts to analyze the association and distinguish the auditory image from the movements connected with it, the image has nothing to support it.

Dermal, Gustatory and Olfactory Images.

Lay gives a list of ten types of mental imagery observed in himself.[1] Besides visual and auditory, he finds *tactile*, of which

[1] Mental Imagery; Psych. Rev. Mon. Sup., VII, p. 36 ff.

he says, "This seems to me as clear and strong as any other, occasionally stronger;" *gustatory*, of which he says, "Sour and sweet are the only tastes I revive quite clearly, the others being three parts visualization and olfactory;" *olfactory*, "These are in my own case extremely numerous;" *thermal*, "The percentage of my own thermal imagery is only 2% and contains such imageries as 'warm feet,' 'cold nose,' etc.;" *motor; imagery of pain*, "I can imagine pain, *e. g.*, that of a stubbed toe, a cut, or a pounded finger;" *organic*, such as hunger, thirst, etc.; and imagery of *emotions*. His method was to make numerous association series, classify and take percentages. The faultiness of the method is evident after a direct examination of the images. Our subjects failed to manifest such an elaborate equipment, as the following series will show.

I. (1) *Feeling of plush.*

St. Got visual image of hand passing over plush. Thought he got plush feel for a moment. Decided "creepy" feeling, due to unpleasantness continued throughout.

K. Visual image of blue plush on back of chair followed by visual and motor of moving hand. Plush feel on fingers was very clear but did not last. Slight pleasantness.

Sr. Could not get it but saw rose colored plush very distinctly. No incipient movements noticed. Effort to get dermal distinct. Visual continuous.

(2) *Clammy hand.*

St. Visual of hand. Clear clammy feel which directly went over to "creepy" feeling. Some shudder. Noticed no tendency to speak word, but distinct tendency to express repulsiveness.

K. Fairly distinct visual of hand clasped in own, then tactual and temperature combined, latter distinct. Motor of grip. Word not present. No affective quality noticed.

Sr. Clear visual of hand. No dermal. Repeated word over and over, and coupled with it feeling of repulsiveness.

(3) *Hot water.*

St. Had fair visual of hand in water. Then of wetness and temperature, not very clear. No tendency to use word.

K. Visualized hand and hot water. Tactual and temperature of water localized in fingers quite clear (mem. from experiment). Organic and affective elements present.

(4) *Plunge into cold water.*

St. Distinct visual image of self going into bath tub, followed by sort of shudder. This kept repeating itself.

K. Visual (mem.) of cold shower bath. Strong organic reaction of chill. Then visual of self jumping into cold river. Saw splashing of water. Repetition several times of organic shiver.

Sr. Less visual setting than usual; seemed to be closing eyes to jump into water. Had all the chilly, spasmodic, shrinking feeling. This was momentary but kept repeating itself (about six times).

II. (1) *Salt.*

St. Flow of saliva seemed to increase. Felt a certain dryness in throat which usually comes when subject tastes salt.

K. Visual, tactual and motor together of mouth, moving tongue and contact with salt. Then for a moment seemed to get taste of salt localized on tongue.

(2) *Bitter.*

St. Seemed to feel some puckering in mouth and setting of muscles as in real bitter. Attention directed to mouth.

K. Nothing very definite. Motor and tactual images of moving tongue. Then vague visual of position of tongue and something on back of it. Fairly clear organic reaction to bitter.

(3) *Sweet.*

St. Nothing but moistening of tongue.

K. Vague visual image of tongue and mouth and vague motor of moving tongue. Then for instant visual (mem.) image of sugar. Then seemed to get a very indistinct taste image of sugar, but tactual and motor very prominent elements. No tendency to pronounce word. Not certain that he did not visualize word.

(4) *Sour.*

St. Seemed to be some change in mouth but could not distinguish what it was.

K. Visual of jug of vinegar (mem). Seemed first to smell it. Then complex of visual and motor with vague feeling of sour on back of tongue.

III. (1) *Ammonia.*

St. First trial, could get nothing. Second trial, thinks there was some kind of tension or irritation in nostrils. No associated images of any kind.

Sd. Nothing that could be called image. Some feeling in nostrils. Visual of bottle of smelling salts. Word seemed more or less present to consciousness. Inhaled. Feeling lasted only a second or two.

K. Nothing very definite. At first, a blank period of trying to recall odor. Inhaled as in act of smelling. Vague visual image of bottle with ammonia label. At last, seemed to get a vague feel of ammonia located in nostrils.

(2) *Alcohol.*

St. Visual (mem.) image of bottle, seemed right under nose. Could feel no sensation in nostrils. Breath a little irregular.

Sd. Visual of laboratory and place where alcohol is kept. Recollection of occasions when smelled it. Whole rather vague. Seemed at last to get some faint whiffs.

K. First, distinct visual of big laboratory bottle with label on it. Motor of breathing. Finally seemed to get some faint recognition of odor image. Not very distinct. Slight feel of temperature, "cool smell."

It is evident that here we have the association process, discussed under auditory images, going a step further. The existence of dermal images in normal persons is extremely doubtful, and the non-existence of taste and smell images practically certain. There never seems to be anything more than what may be called the *intent.* There is a focusing of the associative complex and a special emphasis of the distinctive factors that have attended the sense experience. Frequently a word is

used to fill the gap and satisfy the situation, and there is always a feeling of certainty of being able to recognize the sense experience if repeated. The words referring to these departments, that come out in the association series, are probably based upon actual sense experiences, and when recalled have nothing more than a certain associative value. This, however, is quite sufficient in everyday life, and perhaps the limitation is a necessary one, as a clear taste or smell image would undoubtedly be included in the list of illusions. We can hardly admit dream images as evidence of the actual pressence of taste and smell images because of their general hallucinatory character and the uncritical way in which they are obtained.

The Direction of Images.

Some of the subjects were tested as to the directions in which the images appeared, and the writer has for a long time made careful observation of this characteristic in his own images. It was found that the images of objects shown to the subjects invariably seemed in the same directions as the objects themselves. If an object was shown and the subject wheeled so that it was back of him, he seemed to be looking at it through the back of his head. The same was true of familiar objects about the room. The actual directions were in every case preserved.

Concerning objects not actually present, as houses, rooms, etc., in the vicinity and elsewhere, the following results came out. (1) When the name of an object lying in a definitely known direction is called, as a familiar building in the city, if it has ever been seen from a point on the line of direction from it to the subject, this direction is preserved, the aspect perceptible from that point appearing and seeming to be observed directly from where the subject actually is. For example, if he is sitting in the University laboratory and is told to image the City Hall, there is first a distinct straining in that direction, front, side, or back, according to his position, and then he sees the building directly from where he is and that side of it visible from the street leading toward the University. (2) If the object has not been seen from a point on the line of direction, a double process takes place. There is first a definite feeling of the direction of a point from which it has been seen, accompanied by the appropriate setting of images, frequently with a vague image of the self in that position. Then there is a change in the feeling of direction to that of the object from that point. If the subject is in the laboratory and is told to image the front of the building, there is first a strain in the direction of the street, and then just as definite a strain back.

If every step in the experiment is noticed carefully, it will be seen that there is a rapidly recurring fluctuation from the one sense of direction with its set of images to the other. This is perhaps the reason why images of such objects are much more difficult to hold than those described in the first case. (3) With objects that have lost the particular setting that gives a definite memory quality, by reason of having been seen in many settings, the sense of direction with some is indeterminate, and with others varies in individual cases.

Here, of course, the motor element is of paramount importance. Introspection finds nothing more as a basis for the sense of direction than certain combinations of strains. When an object is localized in front, the eyes are kept in that direction, and there is a distinct release of tension; when localized back of the head, there is a distinct increase of tension in the antagonists; when localized on the side, the eye is drawn partly in that direction. Combined with these eye movements are the minutely graded contractions of head, neck, and even abdominal muscles.

Conclusion.

While our data are insufficient for any very definite or far reaching conclusions, the work seems to throw light upon one or two facts respecting the behavior of images. These are, (a) that the factors which keep visual images in clear consciousness are their own internal organization combined closely with motor elements; (b) that auditory images appear only in connection with an organized associative situation, in which motor elements usually play a predominant part; (c) that images from other sense departments also require such a situation which is, in most cases, all that appears, so that the real existence of these images is doubtful.

There are certain general questions bearing upon the work, whose consideration is necessarily of the most unsatisfactory kind. One of these is whether the images obtained under introspective conditions are the same as the normal working images of everyday life. It may be that voluntary recall and control, and the process of analytical examination produce a result varying considerably from the normal sequence of images. But since introspection is the only means of approaching the images, the question must necessarily remain unanswered.

Another general consideration is that of the means by which a subject is able to critcise his images. In at least two cases, parts of the image were found to be disparate, as when with St the ticking of the watch was too slow, and with K the sound did not fit the dripping water. Apparently there is a standard outside the image itself by which it is tested, and we have to

deal with a situation which is not merely a self-adjusting memory complex. The problem is one which falls within the discussion of recognition and not of images proper.

AN HISTORICAL STUDY OF THE EDWARDEAN REVIVALS.[1]

SAMUEL PERKINS HAYES.

INTRODUCTION.

In the study of any great popular movement it is essential to take account of the mental, moral and physical conditions of the people involved. It has therefore seemed best to recall very briefly some of the most important events in the early history of New England in order to assist us in forming a clear conception of the general state of affairs in the early part of the eighteenth century.

The history of New England might be summarized in one large word—*struggle*. Nature gave almost nothing. From the thin, rocky soil, bare subsistence could be won only by incessant labor and the strictest frugality; the climate made a severe strain upon the stoutest constitutions. Indian wars drained the colonial treasury and almost exhausted the nervous energy of the colonists. In the early period, internal theological conflicts were incessant and in the provincial period, friction with the mother country constantly sapped the vital force of the people. The following list of events will give some idea of the "temper of the times."

1620. Founding of the Plymouth Colony.
1630. Founding of the Massachusetts Bay Colony.
1633–5. Hostilities between Plymouth Colony and French.
1636. Banishment of Roger Williams.
1636–8. Banishment of Anne Hutchinson.
1635–7. Migrations to Connecticut.
1637. Pequot War.
1637. First Synod of Churches.
1640–4. End of Puritan Exodus.
1643. Confederation of the Colonies.
1646–51. Presbyterian Cabal and Cambridge Platform.
1649–51. Oliver Cromwell and the Commonwealth.

[1] This paper is one of a series written by the members of a Seminary in Church History engaged last year in a study of the rise and development of the "New England Theology." The special purpose of this paper was to trace some of the relations between this theology and the revival of religion so aptly named "The Great Awakening." The paper has been somewhat revised.

1656–61. Persecution of the Quakers.
1657–62. Half-Way Covenant.
1660. Restoration of Charles II.
1671–86. Struggle with Charles—Overthrow of the Charter.
1674–78. King Philip's War.
1686–89. Tyranny of Andros.
1692. New Charter of William and Mary.
1689–97. King William's War.
1690. First Colonial Congress.
1692–3. Salem Witchcraft.
1696–1749. Suppression of Colonial Manufactures.
1702–10. Queen Anne's War.
1722–25. War with the Northeastern Indians.
1734–5. Revivals in Northampton and vicinity.
1740–1. Great Awakening.
1744–48. King George's War.
1755–60. French and Indian War.

But especially important for our purpose is the religious history of New England. The great ideal in early Massachusetts was the founding of a Puritan Theocracy—a state fashioned upon scriptural models and ruled according to scriptural teachings. This state was to be composed entirely of Puritan Christians; all others must be rigorously excluded; only church members were to be citizens. But in the attempt to realize this ideal, difficulties were encountered on every side. Strangers came to the colony preaching foreign and conflicting doctrines: these must be silenced or excluded. Hence after an ineffectual attempt to dissuade or silence them, the authorities banished Roger Williams in 1636 and Anne Hutchinson soon afterwards. Between 1656 and 1661 came the long struggle with the Quakers, and although the Puritans were unable either to silence or to exclude *them* and at last accepted the inevitable and ceased persecution, they never really gave up the strict theocratic idea until the issuance of the New Charter of William and Mary (1692) which secured liberty of conscience to all but "Papists" and extended the franchise to all freeholders fulfilling certain property qualifications.

Within the colony, too, there was an ever increasing tolerant party. This is indicated by the constituency gained by Roger Williams and Anne Hutchinson. This tolerant element was also, doubtless, influential in putting an end to the persecutions of the Quakers. Among such "liberals" should be counted (1) the malcontents or "anti-administration party" which tends to develop in every community where one faction holds the power for an extended period, (2) many of the young people born in the colony but chafing under the strict rule of their elders, and (3) all persons who had come under

the influence of the Plymouth Colony of "Separatists," who had come to America to gain freedom of conscience and not to establish a "Theocracy." That differences of opinion on many important subjects existed almost from the beginning, is well shown by the fact that the First Synod of Churches in 1637 succeeded in unearthing "82 opinions some blasphemous, others erroneous and all unsafe," besides "9 unwholesome opinions," all of which it consigned "to the devil of hell from whence they came."

Within the Puritan Theocracy itself an important doctrinal change had gradually taken place which is of vital importance for our discussion, being in fact the central question of the revival theology:—the nature of "regeneration"—the doctrine of the "new birth." The original Theocracy had been composed wholly of church-members, born and reared in England. These people had been baptized in infancy or early childhood, and at maturity, upon experiencing conversion, had been received into the church as apparently regenerate and hence on their way to Heaven. It was the most zealous only that were willing to leave their ancestral homes to brave the unknown perils of the western wilderness. But among those born in New England, especially in the second generation from the settlers, there were many good people who, although duly baptized in infancy, never experienced conversion; and as they were thus never received into "full communion," *their* children were not even baptized. It looked as if many young people were thus drifting away from the church, and to retain them the "Half-way Covenant" was devised (1657–1662) with the provision that descendants of baptized church-members should be baptized and admitted to part of the privileges of church members although not received at the Lord's Supper. This action of course gravely affected popular ideas of regeneration: from being the all-important and central thing in life—necessary even for respectability and citizenship—it was now pushed back into a secondary place, and although it was still regarded as essential for ultimate salvation, the general tendency was to take one's own time about the matter. The final step was taken by "the venerable Stoddard" who in 1707 published a sermon in which he maintained "that sanctification is not a necessary qualification to partaking of the Lord's Supper" and "that the Lord's Supper was a converting ordinance." This theory found ready acceptance and was soon widely adopted in New England. The result was marked. Instead of the strict Calvinism which taught that man was totally depraved and could never do or think anything aright until God had poured out His divine grace and regenerated his life, there arose a sort of Arminian self-suffi-

ciency. Morality, not conversion, now became the chief care in life. And as the unregenerate found themselves quite able to commence and carry on a series of "good works" without supernatural aid, they soon came to conceive this as their chief duty: conversion was God's work—let Him accomplish it in His own time. With this separation of morality from regeneration, conversion itself assumed a mystical, inexplicable character. Moral and capable men found their way even into the pulpits: who could tell whether one had been converted or not, if it did not show in changed conduct? In such a community there was imminent danger of a return to the doctrine of "salvation through works," and Jonathan Edwards's great sermons on "justification by faith" were most seasonable for leading New England back to Calvinism.

There was still another complication in the religious situation. The New Charter had thrown open the colony to invasion from abroad; and very soon theologically heterogeneous elements began to make their appearance. The skeptical and rationalistic tendencies of England found fertile soil in America. Episcopal chapels were erected and the hated Prayer Book used in public services. Even Arianism and Socinianism found able supporters.

Add to all this the rapid turning of popular thought away from internal theological debate toward the great question of the proper relation of the colony to the mother-country, the demoralizing influence of the Indian Wars of the early 18th century, and the unsettling effects of westward migration,—and we can easily understand the "religious apathy,"—the unemotional, intellectual type of religious life—of which the preachers of the period complain so bitterly.

Revivals of 1734–5 and 1740–1.

Such was the condition of New England when in 1727 Jonathan Edwards was called to Northampton, Mass., to act as the colleague of his respected grandfather, Solomon Stoddard. Something must be done and Edwards proved to be the man able to do it. In the fall of 1734 he began a series of sermons directed against the moral and theological evils of his time, which resulted in a wonderful awakening of religious interest, so that "there was scarcely a single person in the town, old or young, left unconcerned about the great things of the eternal world." Before May, 1735, the little town of Northampton with its population of 200 families boasted of "300 souls savingly brought home to Christ," and the people of Northampton, with those of many surrounding towns, were converted from a condition of low morality and religious indifference, to that of exemplary Christians, in feeling and conduct.

This revival of 1734–5 was widely discussed in the Colonies and upon the Continent, and in 1737 Edwards, at the request of Drs. Watts and Guyse, of England, wrote his "Narrative of Surprising Conversions," which spread the news still further. As a result America was prepared for great things when Whitefield, the wonderful young evangelist of the Church of England, came to Boston in 1740. Then began that remarkable series of revivals which has so fitly been named "the Great Awakening." Night after night crowds rushed to hear him, and responded to his stirring appeals with emotional outbursts. Here, and everywhere that he stopped in his great tour through the Colonies, large numbers professed conversion. Everywhere religion revived. Numbers of the ablest ministers of the time took up the work at home, many others became itinerant preachers like Whitefield. Among the most successful were Gilbert Tennent (a Presbyterian of New Jersey who went to Boston soon after Whitefield's departure and became a very successful revivalist), Jonathan Edwards and his pupil Joseph Bellamy, Parsons, Wheelock, Pomeroy and Graham. So strong was the religious movement that few people could keep still and soon there appeared large numbers of lay-exhorters, "men of all occupations who are vain enough to think themselves fit to be teachers of others," "of no learning" and "small capacities," "babes in age as well as understanding," "chiefly young persons, sometimes lads or rather boys—nay women and girls"—even "negroes."

Such a movement is bound to take on extreme forms. This tendency soon developed, and under the lead of such extremists as Barber, who claimed immediate revelation and direction from the Holy Spirit, and Davenport, whose methods were so irrational that a Boston jury and the Connecticut legislature both pronounced him insane—under the lead of such men the emotional element was so emphasized that their religious meetings became little else than riots.

Of course there was a vehement protest against such a development. In this all the best men united. But many went still further and soon we find two distinct parties arising, both regretting the excesses and disorders that had become widely prevalent, but taking different views of their frequency and meaning: one party considering these disorders as exceptions, and looking upon the movement in general as a glorious work of God and therefore to be promoted; the other party considering disorders to be the rule, and true conversions the exception,—and regarding the movement therefore as a work of the devil upon corrupt human nature, and to be heartily discouraged.

THE "OLD LIGHTS" AND THE "NEW LIGHTS."

Jonathan Edwards was far more than a theoretical reasoner; above all things he was a practical worker. Called upon to meet a situation he used the tools at his hands—he preached the Calvinism that was his by birthright and by training—but all the time his mind was intent upon the needs of the times and he used his theology as a means toward the ends of higher morality and purer personal religion. Out of his attempt to explain the facts of his own religious experience and that of many of his hearers in terms of Calvinism, grew up the New England theology; out of his experience in revival work grew up the working principle of the "New Light" party—"Press unto the Kingdom."

A critical study of the results of the revival led Edwards to see a certain well marked series of steps from religious indifference to what he regarded as true conversion. These steps, as he observed them in his own experience and in the experience of others, he tried to explain by his theological system.

First comes the conviction of one's sinfulness and guilt; then a period of intense struggle during which the awakened sinner tries by all sorts of works and religious exercises to set himself right with God—often ending in despair and utter hopelessness of ever attaining justification and salvation; at last there comes to many—not to all—a beautiful peace and joy; all the world seems new; all doubts and struggles subside and the convert's heart is filled with a sense of assurance and peace. To this Edwards applied his Calvinism. Natural man, corrupt by nature, must be awakened from indifference by the strongest possible presentation of the facts of his sinful condition—the infinity of his sin as against an infinite God—and be warned with all the terrors of hell if he continues in such a state. Realizing his perilous condition, man will of course make every effort to save himself. But man is absolutely dependent on God for saving grace, and if God does not choose to elect him, despair and utter hopelessness must be the end of man's efforts. If, on the other hand, God does elect him, conversion—a new nature—will follow and he will be at peace with God, righteous and completely happy. All this has a logical basis in Calvinism. Total depravity, unconditional election and irresistible grace easily justify such preaching and explain its results.

But Edwards saw another fact in the revival movement not so easily accounted for. He observed that a large proportion of those who, after conviction of sin, exerted themselves to get salvation, at last succeeded and showed convincing signs of a changed nature. This pointed in just the opposite direction from unconditional election. Why does God elect the most

zealous? This question Edwards never satisfactorily answered; but on this observed fact, inconsistent as it is with his theological system, he based his whole practical revival work. "Press unto the Kingdom" was the shibboleth of Edwards and his school. "Be violent for the Kingdom of Heaven." Why? Does God save any man for his works? No. Justificaton is by faith alone. Can man save himself? No. Saving grace is the gift of God. Can man even turn to God before God gives his grace? No. Man's will follows his inclination and his inclination is away from God and always must be till God changes his nature and gives man a taste for divine things. Why then preach that man should be violent for the Kingdom? Because scripture clearly commands men to do so, and because observation shows that a large proportion of the most zealous succeed and receive saving grace. This is the "Edwardean paradox"—urging man to turn to God, when, according to the doctrine of total depravity, man is powerless to turn toward God, till God regenerates him.

Such is the basis of the school called "New Lights"—Christian religious experience interpreted by means of Calvinism—Christian religious loyalty and zeal rewarded by success as practical observation shows.

But by another set of men the whole revival movement was explained in another way. The "Old Lights" to be sure were at first conspicuous mainly because of their protests against the emotional excesses and the practical disorders of the movement, but as we look deeper we see that back of all this was the belief that the kingdom of heaven could *not* be thus taken by storm. They had the same Calvinism, but their observations led them to a different conclusion concerning the results of the revival movement. The New Lights claimed many true conversions and admitted incidental disorders. Such being the results the sort of preaching and the methods that attained them must be the best. But when it was claimed that true conversions were few and disorders general, the aspect of the whole subject was changed. Edwards had no Calvinistic basis for his revival watchword "Press unto the Kingdom." The Old Lights denied him a practical basis by claiming that his observations were incorrect. As for the means of grace—God has commanded their use as a preparation for salvation and man must obey God's commands; but as for "pressing unto the kingdom"—this is unscriptural and illogical as is every tendency to persuade or induce God to act before in his sovereign pleasure he feels disposed. We have, then, two distinct parties within New England Calvinism: the "Old Lights" preaching morality and the use of the "means of grace," but consistently leaviug conversion to God

and patiently awaiting his action; the "New Lights" preaching the "Edwardean Paradox"[1] (we are helpless to do anything good till God inclines our wills to Him, but it is our duty to "press into the kingdom") and claiming a practical basis for their position in the success of their preaching as indicated by the large number of converts.

Thus the burden of proof was thrown upon the New Lights. The question became one of an explanation of observations. The New Lights must prove that as a result of their work there had been many true conversions. We shall consider rather fully the list of abuses and disorders against which Chauncy writes in his "Seasonable Thoughts," because this will give us a picture of the movement; but our chief interest must be with Edwards's defence of the movement wherein, while lamenting most of the abuses against which Chauncy writes, he also seeks to give a positive basis for his system by showing the true nature of conversion. If conversion is what he claims it is, then the large number of such converts proves the activity of the Holy Spirit and justifies his method of "pressing into the kingdom."

I. Revival Activity of the New Lights.

As we have seen, enthusiasm for the revival movement was very widespread, and large numbers both of ministers and laymen began to travel about and preach wherever they could get an audience. Whitefield and Gilbert Tennent were very prominent, but they do not fall within the province of this paper. Joseph Bellamy became very famous for his great oratorical powers, holding "the passions of the auditory at his command." Of many other men we hear considerable, but the most important for us is the founder of the New England school—Jonathan Edwards. Just what was his method? What did he preach and how? What were the results?

JONATHAN EDWARDS.

The purpose of Edwards in his revival work was to foster in his hearers a warm emotional type of religion, touched and vivified by a sense of immediate communion with God. This he felt sure would blossom in noble Christian conduct and thus redeem the community from the laxity of morals so prevalent

[1] A popular version of the Edwardean Paradox quoted by Chas. G. Finney in his sermon on "The Traditions of the Elders."

You can and you can't.
You shall and you sha'n't.
You will and you won't.
You'll be damned if you do n't.

at the time. Thus his aim was primarily religious—with morality as the fruit of religion.

The unconverted—the sinner—must be awakened. How? In his natural state man is sinful and has no moral quality to which one may appeal. Hence the appeal is to selfishness—man's hope of future Heaven, rather than Hell. Over and over we find in his sermons the following series of arguments:

1. The unconverted are in a condition of infinite sinfulness—guilty of sin against infinite goodness and love—and therefore justly deserve the infinite punishment which now awaits them and from which only the goodness of God has kept them free up to this time.

2. This punishment is utterly beyond imagination—universal, eternal, intolerable—the most extreme that an infinite God infinitely enraged can invent.

3. The only hope of escape is by the free gift of salvation from God. This cannot be won by man's efforts, but if one is violent in seeking salvation and diligent in fulfilling all the duties God has prescribed, there is a probability that God will give him saving grace—although, of course, He is not bound to do so. Therefore, be violent for the kingdom, give up your whole life to violent endeavors to press into the kingdom. Such discourses, he says, have been the ones most remarkably blessed.

This perhaps does not seem especially awakening to us—the whole scheme may appear ridiculous and tend to raise mirth rather than fear and conviction of sin. But we must not forget the changed conditions of our times. In a day when belief in Hell was as firm and fundamental as our belief in the laws of gravity, what a powerful weapon the preacher had in his hands. The Catholic Church shows us how compelling this belief can be made. Then add to this fact the tremendous power wielded by the man Jonathan Edwards, in whom we find such a striking combination of searching irrefutable logic with a vivid oriental imagination kindled by strong religious emotions and founded upon a most severe but triumphant religious experience; taking all this into consideration is it so surprising or inexplicable that a "great and earnest concern about the great things of religion and the eternal world became universal in all parts of the town and among persons of all degrees and all ages; that "many were awakened with a sense of their miserable condition by nature, and the danger they are in of perishing eternally;" that large numbers were so alarmed as to "immediately quit their sinful practices" and "devote themselves to an earnest application to the means of salvation, reading, prayer, meditation, the ordinances of God's house and private conferences, making constant inquiry 'What shall we

do to be saved?'" that some were so overcome with fear as to cry out in the midst of the service, or to weep or turn pale, or even fall into convulsions; that some, indeed, were so affected that their health was impaired causing them to sink down under the intensity of their contending emotions. Perhaps it will be well to look at some of the revival sermons of Edwards in detail. Take for instance his famous sermon preached at Enfield, July 8, 1741, upon the text "Their foot shall slide in due time," from Deut. 32:35, entitled "Sinners in the hands of an angry God." His proposition is "There is nothing that keeps wicked men at any one moment out of Hell, but the mere pleasure of God." This he discusses under ten headings: (1) "There is no want of power in God to cast wicked men unto Hell at any moment." (2) "They deserve to be cast into Hell; so that Divine justice never stands in the way; it makes no objection against God's using his power at any moment to destroy them." (3) "They are already under a sentence of condemnation to Hell." (4) "They are now the objects of that very same anger and wrath of God that is expressed in the torments of Hell." (5) "The devil stands ready to fall upon them and seize them as his own at what moment God shall permit him." (6) "There are in the souls of wicked men those hellish principles raging that would presently kindle and flame out into hell fire, if it were not for God's restraint." (7) "This is no security to wicked men for one moment that there are no visible signs of death at hand." (8) "Natural men's care and prudence to preserve their own lives or the care of others to preserve them does not secure them a moment." (9) "All wicked men's pains and contrivances which they use to escape Hell, while they continue to reject Christ and so remain wicked men, do not secure them from Hell one moment." (10) "God has laid himself under no obligations by any promises to keep any natural man out of Hell one moment."

By way of application Edwards pictures the everlasting torments of hell in glowing colors, and enlarges at length upon the infinitely terrible wrath of his angry God, with a reiteration of the utter impossibility of escape for sinners unconverted. But now is a time of "extraordinary opportunity, a day wherein Christ has thrown the doors of mercy wide open and stands calling and crying with a loud voice to poor sinners—a day wherein many are flocking to him and pressing into the kingdom of God." "Therefore let every one that is out of Christ and hanging over the pit of Hell now awake and fly from the wrath to come."

This sermon can easily be parallelled by many others; as, for example, that of May, 1735, entitled: "Wrath upon the

wicked to the uttermost;" that of April, 1739, upon "The Eternity of Hell Torments;" or that of April, 1741, to prove "The Future Punishment of the Wicked Unavoidable and Intolerable."

Of course Edwards preached upon other subjects also, but the sermons that awakened his hearers were those that appealed to the emotions, especially the emotion of fear, cast in the form of cold logic but illumined with a surprising wealth of brilliant and vigorous imagery.

DAVENPORT AND THE EXTREMISTS.

But, as we have seen, there was another wing of the new lights whose violent measures and emotional excesses brought the whole movement into disrepute. Of these men the most prominent was James Davenport, whom Chauncy seems to regard as the most extreme example of all the "Things of a bad and dangerous tendency," against which he writes his "Seasonable Thoughts upon the state of Religion in New England." "It is well known," he says, "no preacher in the new way has been more noted for his instrumentality in producing these shriekings and faintings and tremblings than the Rev. James Davenport, of Southold." And one of the charges exhibited and proved against this Mr. Davenport, when brought before the General Assembly of Connecticut, was that "he endeavored by unwarrantable means to terrify and affect his hearers," namely "(1) By pretending some extraordinary discovery and assurance of the very near approach of the end of the world.

"(2) By an indecent and affected imitation of the Agony and Passion of our blessed Saviour, and also by voice and gesture, of the surprise, horror, amazement of persons supposed to be sentenced to eternal misery. And

"(3) By a too peremptory and unconditional denouncing damnation against such of his auditory as he looked upon as opposers, vehemently crying out that he saw hell flames flashing in their faces and that they were now! now! dropping down to Hell!"

"An account of Mr. Davenport's preaching," says Chauncy, "not altogether unlike this, a gentlemen in Connecticut wrote to one of the ministers of this town, upon his own knowledge, in these words: 'At length he turned his discourse to others and with the utmost strength of his lungs addressed himself to the congregation under these and such-like expressions, viz.: You poor unconverted creatures in the seats, in the pews, in the galleries, I wonder you don't drop into Hell! It would not surprise me. I should not wonder at it, if I should see you drop down this minute into Hell. You Pharisees, hypocrites;

now, now, now you are going right into the bottom of Hell. I wonder you don't drop into Hell by scores and hundreds. Etc.' And in this manner he ended the sermon! 'T is then added: After a short prayer he called for all the distressed persons (which were near twenty) into the foremost seats. Then he came out of the pulpit and stripped off his upper garments and got up into the seats and leapt up and down some times and clapt his hands together and cried out in these words: 'The war goes on, the fight goes on, the Devil goes down, the Devil goes down;' and then betook himself to stamping and screaming most dreadfully. And what is it more than might be expected to see people so affrighted as to fall into shrieks and fits under such methods as these?' "

Just how much there was of this extreme sort of work it is very hard to determine accurately. Chauncy arraigns Messrs. Pomeroy, Wheelock, Allen and Bliss as being of one soul and as having the same method of conduct as Davenport, "though I believe," he says, "Mr. Davenport has outdone them all." Chauncy does not attribute such excesses to Edwards, nor does he make this his main criticism of Whitefield and Tennent, but he considers such work to be the logical result of emotional preaching; and because of the wide prevalence of such excesses he is convinced that the Revival is not the work of the Holy Spirit and should be suppressed.

II. Criticism of the Revival Movement by Chauncy.

As we have seen, the great question at issue between the Old and the New Lights was "what shall we do to be saved?" The New Lights pointed to large numbers of professing converts and said, "See; those men got salvation by being violent for the kingdom of heaven; therefore that is the proper way. We of course do not claim that man can thus save himself, but observation teaches us that this method succeeds." The Old Lights replied: "A good part of your professing converts are no converts at all. The movement has been a series of emotional outbursts which are no sign of true conversion, and the unchristian spirit of many of the leaders of the movement, together with the disorders and extravagances which have been everywhere prevalent, prove that the movement is not a work of the spirit. True conversion is always marked by a change of nature, and a changed nature always blossoms into the fruits of the Spirit which are described in Scripture." Thus, the real question is the nature of true conversion. Chauncy and Edwards both claim that conversion consists in a change of nature, and both see in Christian conduct the chief sign of this regeneration, but Edwards's idea of the affections as a great part of true religion is lacking in Chauncy, and as a result

those emotional excesses which are so easily disposed of by Edwards are an insuperable barrier to Chauncy, and lead him to an opposite opinion of the revival as a whole.

In Chauncy's opinion the fundamental error of the revival movement is the belief that true religion consists in emotional expressions and not in Christian conduct; and from this belief spring the various disorders and excesses against which he writes.

1. Errors in Doctrine. These may be thus summarized: If true religion consists in emotional expressions, then the more emotion one has the more religious one is; and since all religion is impossible to man in his corrupt natural state, such an emotional awakening is clear proof that God's saving grace is working within him. Emotion being a sign of the presence of the Spirit it is possible for every one to know whether he is savingly converted and to tell the same of his fellows—whether laymen or ministers. The ability to state the exact time and circumstances of one's first emotional awakening is a proof of one's conversion. If one cannot tell when he was converted doubtless he is not converted. With the spirit in one's heart working to save, what need has man to perform the "means" of grace which God intended only as a preparation for the Spirit's coming? How natural to attribute dreams and unusual visions and the sudden remembrance of Scriptural texts to the direct inspiration of the Spirit and therefore to claim for oneself special divine guidance in all the acts of life—in deed and speech—such as the Apostles enjoyed!

2. Errors in Practice. Such theories are very fruitful of erroneous methods.

(A) *Appeal to Emotions.*

If emotion is the essence of religion, and bodily effects the clearest signs of its presence, then any methods which tend to arouse the emotions are legitimate—nay, most admirable. Hence the great effort to induce extreme fear in the minds of the hearers with "all the terrible words they can get together and in such a manner as to naturally tend to put weaker minds out of possession of themselves," so that "'tis no unusual thing for persons to be plunged into the utmost agony and distress, which is often attended with a trembling of the body, fainting, falling down, etc."

"The way in which these fears have been excited in many places is not in my opinion (he says) the best evidence in favor of them. People have been too much applied to, as though the preachers rather aimed at putting their passions into a ferment, than filling them with such a reasonable solicitude as is the effect of a just exhibition of the truths of God to their

understandings. I have myself been present when an air of seriousness reigned visibly through a whole congregation: they were all silent and attentive, having their eye fastened on the minister as though they would catch every word that came from his mouth; and yet because they did not cry out or swoon away, they were upbraided with their hardness of heart, and ranked among those who were sermon-proof, gospel-glutted, and every topic made use of, with all the voice and action the minister was master of, to bring forward a general shriek in the assembly; nay, in order to give the people a plain intimation of what he wanted, this same preacher sometimes told them of the wonderful effects wrought by the sermon he was then preaching—how in such a congregation they were all melted and dissolved, and in another so overpowered that they could not help screaming out or falling down as though they had been struck dead. Nay one of the preachers in this new way was so open, some months ago, as in plain words to call on the people to cry out, and plead with them to do so. This he did several times in one sermon, and had upon it so many loud cries. And 't is too well known to need much to be said upon it that the gentlemen whose preaching has been most remarkably accompanied with these extraordinaries, not only use in their addresses to the people all the terrible words they can get together, but in such a manner as naturally tends to put weaker minds out of possession of themselves." Then follows an account quoted from the letter of a friend in the country, whose record, Chauncy assures us, may be relied upon, "For it is given by one capable of making observations, and who bears as unblemished a character as most ministers in the country." This record is as follows:

"Under the preaching and exhortations of these itinerants and exhorters (the manner of which is frequently very boisterous and shocking, and adapted to the best of their skill to alarm and surprise the imagination and passions), 't is no unusual thing for persons to be plunged into the utmost anxiety and distress, which is often attended with a trembling of the body, fainting, falling down, etc. The preacher now frequently grows more tempestuous and dreadful in his manner of address, and seems to endeavor all he can to increase and spread the rising consternation and terror of their souls, which by this means is sometimes spread over a great part of an assembly, and in a few minutes from its first appearance. I have seen the 'struck' (as they are called) and distressed brought together from the several parts of the assembly into the square body by themselves, smiting, stamping, and crying out to them with a mighty voice in the most terrible manner and language: the poor creatures fainting, screeching, and bitterly crying out

under them. You may easily think what terrors of imagination, distraction of passions, and perplexity of thought they endured. I was last summer at an evening lecture at a neighboring parish, at which one of the most famous preachers in the new method carried on. He had entered but a little way in his sermon (which was delivered in a manner sufficiently terrible), when there began to be some commotion among the young women. This inspired him with new life. He lifted up his voice like a trumpet, and plentifully poured down terrors upon them. About half a score of young women were presently thrown into violent hysteric fits. I carefully observed them. When he grew calm and moderate in his manner, though the things delivered were equally awakening, they by degrees grew calm and still; when he again assumed the terrible and spake like thunder, the like violent strugglings immediately returned upon them from time to time. Sometimes he put a mighty emphsis upon little unmeaning words, and delivered a sentence of no importance with a mighty energy, yet the sensible effect was as great as when the most awful truth was brought to view."

A similar account Chauncy quotes from the Boston Post-Boy, No. 391, which speaks of itinerant preachers as follows: "Their main design in preaching seems not so much to inform men's judgments, as to terrify and affright their imaginations: by awful words and frightful representations to set the congregation into hideous shrieks and outcries. And to this end, and in every place where they come, they represent that God is doing extraordinary things in other places, and that they are some of the last hardened wretches that stand out; that this is the last call that ever they are likely to hear; that they are now hanging over the pit of destruction, and just ready this moment to fall into it; that hell fire now flashes into their faces, and that the devil now stands ready to seize upon them and carry them to hell; and that they will often times repeat the awful words 'Damned! Damned! Damned!' three or four times over."

(B) *Censoriousness.*

If strong emotions give one assurance of conversion, it is easy to conclude that those who have not experienced the same kind of awakening are unconverted—are therefore not true Christians and certainly no fit persons to occupy the pulpits of the land. This censorious spirit "appeared first of all in Mr. Whitefield, who seldom preached but he had something or other in his sermon against unconverted ministers." And as though he had not done enough in preaching he expressed his

fears in his Journal of New England lest "many, nay the most that preach do not experimentally know Christ."

Gilbert Tennent showed a like spirit. Chauncy says "His preaching in Boston was censorious beyond what can be easily imagined." "But the most remarkable instance of this kind is the Rev. Mr. James Davenport, of Southold," who was so violent in abuse of the ministers that many refused to let him preach in their pulpits, and when brought to Court for his libellous conduct he was acquitted only on the ground that to use such language he must be "*non compos mentis.*"

This same censorious spirit soon became widespread all over the country among the common people, "Parents condemning their children and children their parents, etc."

(C) *Claim of Immediate Inspiration.*

If religious emotions are a sign of the presence of the Holy Spirit, how natural it is to claim that verses of Holy Scripture coming into the mind with great force and peculiar fitness to one's conditions are the direct gift of the Holy Spirit and intended to guide one's conduct; that dreams and visions and unusual imaginations are the result of special revelation; that in this time of special outpouring of the Spirit one should depend on such special illumination to guide one in even the most trivial matters or wait for promptings from the Spirit before acting at all.

"Mr. Whitefield," says Chauncy, "had evidently a turn of mind too much disposing him toward this way" of interpreting impulses, coincidences and dreams as revelations.

Davenport was extreme in this tendency as in many others, claiming divine guidance in daily conduct and revelations of various kinds, laying special emphasis upon "some extraordinary discovery and assurance of the very near approach of the end of the world," and even attempting to cure "a poor woman, living in the next parish to Mr. Davenport's, counted religious, who had been totally distracted for a long time and dumb for a season. Mr. Davenport, possessed with a notion (says Chauncy) that he could pray her into her right mind and to the use of her tongue, though the Philistines could afford her no relief, spent a day of fasting and prayer for that purpose, with a number of his admiring brethren. At this meeting (I think it was) he set a certain day, by which time, if not before, he was assured she would be delivered and recover her speech. On that very day the woman died without having spoken a word or discovering any sign of being in her right mind. When this was objected to him he said his faith was verified and his prayer answered in the event; for that she was delivered that very day by being received to Heaven."

Yet even Davenport was outdone in claims of spiritual direction by his friend and companion Barber. Upon hearing of Whitefield's successes Davenport and Barber "applied themselves in an extraordinary manner to seek of God this outpouring of his Spirit upon the land," and "particularly that he would please more fully to instruct them what he was about to do and give them a great share of the Spirit." After a time certain texts were "powerfully impressed upon Barber's mind" and he began itinerant exhorting. As he counted that he had a special prophetic mission from God "somewhat like that of our Lord's disciples," "he took no money with him, neither change of apparel nor shoes, but was shod with boots; and as he passed along through the several parishes of Southold he publicly declared that he had laid aside all study and forethought of what he should deliver in his public speeches to the people (some who heard him thought so) and depended wholly on the immediate direction of the Holy Ghost, and that it was given him in that hour from time to time what he should say." Finally he reached an obscure place called Oldman "where he abode some months, refusing for a long time to preach to them any more," "neither could he be persuaded to remove thence" but "led an inactive, idle life till he was grown very fat and ragged, alleging in his justification that he had received no direction from the Spirit to remove thence, and must remain stationed there so long as the Cloud abode upon the Tabernacle."

Standing upon the same claim of immediate inspiration and direction were also the numerous lay exhorters who with "presumptuous dependence upon the Blessed Spirit despised learning (speaking slightly of schools and colleges) under the notion of immediate impressions from the Spirit, and that his assistance would more than supply the want of learning," and by neglecting Bible study and the means of grace therein appointed "reflect dishonor upon the written revelations of God."

(D) *Itinerant Preaching*

This custom was a natural development of the aggressive policy of the New Lights Party. The method had its rise, says Chauncy (at least in these parts), from Mr. Whitefield who was soon imitated by Gilbert Tennent. The scheme appealed to others and soon "the method of itinerant preaching became common." Edwards and Bellamy both made preaching tours, and Davenport and Barber with many others almost totally deserted their parishes and spent their whole time in such trips. This was a favorite method with lay-exhorters, who in many ways made themselves a nuisance.

This practice Chauncy vehemently attacks as improper in principle and pernicious in results.

(1) Ministers have no right to desert their own parishes without the consent of their congregations.

(2) Itinerants of any kind have no right to enter other men's parishes unless invited, and then should not take all the credit for results, but should consider the preparation made in the work of the regular pastor. Especially evil is the system when the itinerants push in against the wishes of the settled ministers.

(3) "The tendency of this practice is confusion and disorder." It tends to dissolve the connection of each pastor with his people if the pastor constantly deserts them. It leads to division of congregations into parties and the formation of separate bodies—especially as most of these itinerants claim spiritual direction and are very censorious of all who oppose them or disagree with their views.

Such then is Chauncy's criticism of the Revival Movement. It is founded on a wrong conception of what true religion is, and so has unduly magnified the emotional element in religion, leading to all sorts of excesses and extravagances. It has been carried on by methods which are inexcusable; it has been attended with numerous harsh and unchristian attacks upon those who do not sympathize with it; it has resulted in all sorts of confusion in public worship and in the government and harmony of the church bodies—unfair attacks upon settled pastors and the division of many churches into separate congregations; and far from promoting Christian life and showing those results which are the legitimate and Scriptural fruits of the Spirit it has led to Spiritual pride, censure, conflict, idleness, a neglect of the appointed "means of grace" and a dishonoring of Holy Scripture.

3. True Work of the Spirit.

But the Old Lights were more than a mere party of opposition. They too had positive theories of man's natural state, his need of conversion, the nature of conversion and its results. Their doctrine was the Calvinism with which Edwards started, colored a little with rationalism and Arminianism.

Chauncy's Idea of a Work of the Spirit.

Chauncy looks upon man as in a state of natural corruption. He stands in the greatest need of "that real change of heart and life without which one cannot be qualified for an admission into the Kingdom of God." This change of nature, called in Scripture "sometimes the new Birth, sometimes the Spirit's Renovation, sometimes Conversion or a being turned from

darkness to light and from the power of sin and Satan unto God," is entirely the result of the free action of God's Spirit upon man. God uses various means and instruments to effect this change, but in substance it is the same "in all places and among all people under Heaven." Generally there is first a preparation in the minds of sinners, "whereby God opens to the sinner a vision of himself in his sinfulness and guilt upon which he is driven out of his former case and filled with anxiety and distress." "This is called by Divines Conviction." After this preparation begins the real work of God which is secret and hidden, "effected in the universal frame of their mind. It principally lies in a new heart, another soul, in other views and intentions, other thoughts, sentiments, other principles and springs of action." And when this transformation of nature is complete the new Christian character shows itself in cessation from sin, and a high degree of love, joy, peace, righteousness, holiness and such fruits of the spirit as are indicated in Scripture. This new nature, or "temper of mind" is a "never failing source of good works," and while no one can have absolute assurance of salvation, and "good men may be in the dark about their spiritual condition," yet it is much more likely that those who show "the fruits of the Spirit" mentioned in the Bible, are really acting under the influence of saving grace than those who give no such signs of a changed nature; and as for special revelations, etc., "the least spark of true Christian charity is a better evidence of a work of God in the soul than the greatest ability to show signs and work wonders." Moreover man has something to do. He cannot earn salvation, for this is the gift of God, and of course he cannot "press into the kingdom" against God's will; but God has appointed certain means to be attended in order to the obtainment of that help from the Spirit which is needed for salvation; such as "prayer, reading and hearing God's word and the like," and while he must guard against "the error of placing works in the room of Christ or of free grace," yet "neither the grace of God nor the merits of Christ take away the necessity of a holy life in conformity to the precepts of the Gospel," and "'t is plain, from the same Scriptures, that salvation by Grace through Christ is in the way of obedience—such an obedience as proceeds from a heart purified by faith and purged from dead works to serve the living God." God "no more ordinarily begins than carries on the work of faith as respects its existence and operation in the hearts of sinners without the concurring use of their power and endeavors." "God and man and means are all concerned in salvation."

III. Defence of the Revivals, by Edwards.

While heartily in sympathy with the movement and one of the chief agents in its spread, yet Edwards at an early date recognized the danger and vehemently opposed the excesses and confusions which appeared in many quarters. In 1742 appeared his "Thoughts Concerning the Present Revival of Religion," 74 pages of which he devotes to "showing what things are to be corrected or avoided, in promoting this work or in our behavior under it." Among these we find many of the same things against which Chauncy contended—(1) "censuring professing Christians of good standing in the visible church, as unconverted," attacking ministers as unregenerate "because they seem in comparison with some other ministers to be very cold and lifeless in their ministerial performances," or because of their opposing the revival movement; (2) "spiritual pride"—having a high conceit of one's own light and humility and leading to undue assurance of one's own salvation, the use of harsh and terrible language toward those deemed unconverted, "unsuitable and self-confident boldness before God and man," an improper assumption of authority in speech and conduct and often the affecting of "singularity in external appearances" or a "singular way of speaking;" (3) claims of immediate inspiration and revelation from God to guide his saints by means of scripture or impressions and impulses, with belief "that persons ought always to do whatsoever the Spirit of God (though but indirectly) inclines them to do." (4) disregard of consequences that may arise from methods which serve for present edification, such as the careless introduction of "things new and strange and that have a tendency by their novelty to shock and surprise people" and leading to persecution and opposition which in the end will hurt the cause of vital religion;" (5) disregard of external order in matters of religion and use of the means of grace"—confusion in public worship, "singing in the streets going to and coming from worship," neglecting regular family worship and staying "abroad late in the night at religious meetings;" and finally, (6) lay exhorting. Yet while freely admitting all these errors and irregularities and heartily opposing them, Edwards feels that when the movement is judged as it should be, "by its effects and not by its supposed causes," by the whole teaching of scripture and not by a part only, or by one's own experience or by philosophy, or by the history of earlier religious movements[1] which have either shown none of the good effects of this movement or only an exaggerated degree

[1] For earlier revivals, see preface of Chauncy's Seasonable Thoughts and beginning of Edwards's Narrative of Surprising Conversions.

of its imprudences and excesses, and when the movement is regarded as a whole, separating the good from the bad and not viewed in part,—if thus judged, Edwards feels confident that all will agree with him that the imprudences and disorders of enthusiasts are incidental and exceptional, and the movement as a whole a glorious work of God. As such, Edwards deems it his duty to defend and promote the work; and in 1746, after the emotional excitement of the movement had largely subsided and theological questions were becoming dominant in public thought, he published a book in which he sought to get at the very root of the question. This he called "A Treatise Concerning Religious Affections," giving us (1) a discussion of the nature of the affections and their importance in religion, showing (2) why there are no certain signs indicating whether or not religious affections as such are truly the work of the Spirit, and (3) indicating what are distinguishing signs of truly gracious and holy affections, *i. e.*, what are the scriptural results of the workings of the Spirit.

NATURE OF THE AFFECTIONS.

"God has endued the soul with two principal faculties:" the (1) understanding—"that by which the soul is capable of perception and speculation or by which it discerns and judges things"—and (2) the will or inclination—"that by which the soul is some way inclined with respect to the things it receives or considers—or the faculty by which the soul beholds things, not as an indifferent, unaffected spectator, but either as liking or disliking, pleased or displeased, approving or rejecting." "The more vigorous and sensible exercises of the will are called the affections. The will and the affections of the soul are not two faculties; the affections are not essentially distinct from the will."

In some sense the affections differ nothing at all from the will and inclination, and the will never is in any exercise further than it is affected. "The affections are no other than the more vigorous and sensible exercises of the inclination and will of the soul."

"All the exercises of inclination and will are concerned either in approving and liking, or disapproving and rejecting; so the affections are of two sorts—they are those by which the soul is carried out to what is in view, cleaving to it or seeking it, or those by which it is averse from it and opposed to it. Of the former sort are love, desire, hope, joy, gratitude, complacence. Of the latter kind are hatred, fear, anger, grief and such like."

NATURE OF TRUE RELIGION.

"Religion consists in great part in the affections," "in the vigorous and lively actings of the inclinations and will of the soul or the fervent exercises of the heart." This is clearly the kind of religion God insists upon in scripture. It is the kind of religion Christ and the eminent saints of the Bible had; and it follows in reason that as "God hath so constituted human nature that the affections are very much the spring of men's actions," therefore, "religion must consist very much in the affections." True religion of course involves the whole man, and therefore the understanding as well as the will and inclination is called into action; but "true religion consists so much in the affections that there can be no true religion without them."

NATURAL INABILITY.

The object of a religious man's thought of course is God. What conception can man form of God? What is essential to true communion? God's qualities are of two kinds — his natural perfections such as his power, knowledge, eternity, etc., and his moral perfections, such as his holiness and love. Natural men may have a sense of God's natural perfection and experience such feelings as fear, admiration, joy, etc., but of God's moral perfections natural man can have no conception. Yet it is on the moral excellencies of God that all truly holy affections are primarily founded. Moreover, natural man has no inclination, no taste for such things and therefore can never have any truly religious affections which consist of a vigorous exercise of the will and inclination towards God. Hence to have true communion with God, man's nature must be changed. This occurs at conversion.

NATURE OF CONVERSION.

Conversion is accomplished by the influence of the Spirit dwelling in men's hearts as "a principle of new nature, or a divine supernatural spring of action." The result of this indwelling of the Spirit is that the convert receives as it were a new spiritual sense—as "different from any former kinds of sensations of the mind as tasting is diverse from any of the other senses." Yet this new spiritual sense is not a new "faculty" but a new principle of nature, a new spring of action. Man continues to use "understanding," but with this new spiritual power he is able to gain "a cordial sense of the supreme beauty and sweetness of the holiness or moral perfection of (God and) divine things." Man continues to use his other faculty,—the will or inclination, but with this changed nature comes an inclination towards God instead of towards

sin. Thus both his faculties are affected and with the new view of God's moral perfections and the new taste for divine things come those truly religious affections which consist in a vigorous exercise of the will and inclination toward God for his moral excellence.

FRUITS OF THE SPIRIT, IN LIFE AND CONDUCT.

Very widespread has been the mistake of attributing to the action of the Spirit many effects which are no signs, either of the presence or absence of the Spirit. Such a mistake has encouraged excesses and helped to bring the whole movement into disrepute.

The following things,—we can now perceive—are no signs either of the presence or the absence of the Spirit, for while they may accompany true conversion, they may also be produced where there is no true couversion, merely by the exercise of man's natural powers:

(1) A high degree of religious affections.
(2) Great effects on the body.
(3) Fluency, fervor, or abundance of religious talk.
(4) That religious affections arise without any effort on our part to excite them.
(5) That religious affections come to the mind in a remarkable manner with texts of Scripture.
(6) That there is an appearance of love in them.
(7) That there arise many kinds of religious affections together.
(8) That comforts and joys follow a certain order in appearing.
(9) That they dispose persons to be zealous in religion.
(10) That they dispose persons to praise and glorify God.
(11) That they make persons confident of salvation.
(12) That the accounts persons give of them are very affecting.

"Nothing hinders but that all these things may meet together in man and yet they be without a spark of grace in their hearts."

On the other hand there are certain distinguishing signs of the presence of the Spirit,—that is, there are certain effects which will always follow if the Spirit is present, but it must not be assumed that God has given us any signs by which to be absolutely certain that we ourselves, or any others, are savingly converted. ("Let no saint however eminent and however near to God, think himself out of danger.") These signs, then, do not prove the presence of the Spirit, but merely indicate it. Their absence, however, is good proof that the Spirit is absent.

(1) True religious affections, as we have seen, arise from the indwelling of the Spirit, which by Divine operation upon man's nature transforms it, giving a new sense by which man may rejoice in the moral excellence of divine things, enlightening the understanding and inclining the will towards God.

(2) The result of this transformation within is seen outwardly in the daily conduct of the convert. The regenerated Christian will show tenderness of heart, "such a spirit of Christian meekness, quietness, forgiveness and mercy" as appeared in Christ, and all the scriptural fruits of the Spirit in "beautiful symmetry and proportion." This outward change in the Christian is the great sign of the Spirit's presence to oneself and to one's fellows. "Christian practice is the sign of signs in this sense, that it is the great evidence which confirms and crowns all other signs of godliness." It is "as much the proper experiment and evidence of the superior inclination of the heart as the motion of the balance with different weights in opposite scales, is the proper experiment of the superior weight."

Such is Edwards's defence of the Revival Movement. In his opinion large numbers had been savingly converted; they had experienced true religious affections, and showed in their changed outward lives clear evidence of their new nature.

Half Century of Religious Apathy.

The Revival activity of 1735–42 was followed by a half century of popular indifference and a low status of religious and moral life. The action of the Connecticut May Court of 1742, in forbidding itinerant preaching, and the condemnation of many of the revival methods by the "Annual Ministerial Convention" of May, 1743, did much to cool religious enthusiasm. As a result of this and the wide spread opposition to many of the revivalists for their censorious spirit as well as their extravagant methods, Whitefield on his return to America in 1744 found a poor field for work and was met with intense opposition from the ministers and colleges which he had so rashly censured. Then came the doctrinal discussion accompanying the development of the New Light principles, and political and military troubles with France and Great Britain, and there seemed no chance for religion until the end of the century.

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Festschrift Wilhelm Wundt zum siebzigsten Geburtstage überreicht von seinen Schülern. (Philos. Studien, Vols. 19 and 20.) W. Engelmann, Leipzig, 1902. pp. 615 and 712.

Professor Wundt had many honors showered upon him on his seventieth birthday including the freedom of the city of Leipzig. Perhaps, however, of all the honors most prized by a German savant is a Festscrift composed of works of his own former pupils, now numerous and scattered in nearly all lands. This has taken the form of a 19th and 20th volume of his Philosophische Studien, and comprises articles by Frank Angell, P. Barth, B. Bourdon, J. McK. Cattell, Jonas Cohn, Ottmar Dittrich, Otto Fischer, Ewald Flügel, Willy Hellpach, Charles H. Judd, Friedrich Kiesow, A. Kirschmann, Edmund König, Emil Kraepelin, Oswald Külpe, Paul Rostosky, E. W. Scripture, Ludwig Lange, Alfred Lehmann, G. F. Lipps, E. Meumann, Erich Mosch, Edward A. Pace, Raoul Richter, Bastian Schmid, G. Störring, G. M. Stratton, Karl Thieme, E. B. Titchener, A. Vierkandt, W. Weygandt, Wilhelm Wirth, Julius Zeitler.

Grundzüge der Psychologie, von HERMANN EBBINGHAUS. Band 1. Veit & Comp., Leipzig, 1902. pp. 694.

The first book is devoted to general questions concerning the soul, consciousness and unconsciousness, and the methods of Psychology. The second treats of the structure and functions of the nervous system. The third part considers the simplest psychic forms—first sensations and their specific qualities—to which about one hundred and fifty pages are devoted. Then follow a characterization of sensations in their general peculiarities and relations to time, space, movement, similarity and difference, unity, multiplicity, and the relations to the stimulus. Conceptions, feelings and will follow. The fourth book deals with the most general laws of psychic life, the contemoriety of psychic forms, their sequence, reproduction in experience, memory, habit, repetition, and, finally, relations of psychic processes to movements.

The Home Life of Borneo Head-Hunters: Its Festivals and Folk-Lore, by WILLIAM HENRY FURNESS. J. B. Lippincott Co., Philadelphia, 1902. pp. 197.

The writer spent twelve months in Borneo and attempts to give an unprejudiced impression of the savages he saw. It is a thoroughly unique and sympathetic narrative, copiously illustrated with several scores of photographs taken on the spot. Passionate as is the love of these people for adding to their collection of heads, which always hang over the fire in their long communal houses, and gross as is their idolatry, they are, nevertheless, on the whole attractive people as they are described in this book. They are entirely peaceable among themselves, more chaste and industrious than most savages, cheerful, but clinging tenaciously to their customs, tattooing elaborately, etc. The great charm of this book is, in a word, that the author has gone to the sources and has told us in a frank way, utterly unencumbered by erudition, exactly what he saw among people who, in some cases

had never seen a white man. The tribes, he visited, are simply adult children, excitable, very superstitious especially of omens and taboos, and many of both sexes have magnificent physiques. Abhorrent as the custom is, perhaps the greatest achievement of the author is that he even makes us understand to some extent the strange instinct on which head-hunting rests.

Vergleichende chemische Physiologie der niederen Tiere, von OTTO VON FURTH. G. Fischer, Jena, 1903. pp. 670.

This comprehensive work really marks off a new field. After a few brief sections on preliminary chemical ideas, the author proceeds to discuss the blood of worms, mollusks, crustacea, insects, etc.; then takes up respiration and its organs in the lower forms of aquatic and land life. The third section discusses the nutrition of protozoa, echinoderms, worms, mollusks, crustacea, arthropods, etc., and compares them. Secretion follows next, then animal poisons, then special secretion such as coloring matter, muscine, silk and wax. The muscles are next discussed, then the frame work of the body, the pigments of the different orders of life, residual matter or glycogen, fat, lime and ash, the lips of the sexual glands, with a chapter of especial interest on the chemical conditions of existence among invertebrates. A vast body of interesting matter with tables, literature, and index of both topics and authors follows. It seems to a layman in the subject to be a masterly piece of work.

Development and Evolution Including Psycho-physical Evolution, Evolution by Orthoplasy, and the Theory of Genetic Modes, by JAMES MARK BALDWIN. The Macmillan Co., New York, 1902. pp. 395.

This work is divided into three parts; the first entitled the problem of genesis, consisting of matter that has largely been printed before; part two, the method of evolution; and part three, criticisms and interpretation. These two latter parts are "mostly new matter." Here the problems, which the writer treats with "hope with sufficient fear," are the exposition of the psycho-physical evolution and the outline sketch of the theory of genetic modes. As a whole, the work is abstract with great stress laid upon method. A copious appendix contains various papers of the author up to date, with quotations from H. F. Osborn, statements of Lloyd Morgan, discussions with Poulton, Headley and Conn, and various reviews.

Dictionary of Philosophy and Psychology. Edited by JAMES MARK BALDWIN. Volume 2. The Macmillan Co., New York, 1902. pp. 892.

The author and his many coadjutors present here the remainder of their dictionary from "Leading of Proof" to "Zwingli." Then follow indexes of Greek, German, French, and Italian terms. A third bibliographic and biographic volume is to follow.

The service of this comprehensive work is sure to be great and something of the kind has long been sadly needed. Of course the work of the different co-laborers varies greatly in value as does the work of the same writer upon different themes. Sometimes extremely valuable and new matter is given in pithy form, and the reader will know that some of even the longer articles are perfunctory and aridly general. All psychologists will, of course, welcome such a volume.

Grundzüge der Psychologie, von HUGO MÜNSTERBERG. Leipzig. 1900. pp. 562.

This volume, although more than two years old, has just been re-

ceived, December, 1902. The writer first treats the problem of psychology; its present tendencies; its epistemological basis; its relations to history, science, and life. The second part, on psychic objects, discusses the relation to consciousness, to space and time; psychic manifoldness, and a description of the psychic objects. The third part, on psychic connection, treats of connection through the soul, the body, the apperception theory, biological explanation, theory of association and of action. A good part of this work, and that the most characteristic, has already appeared some two years ago in an English and American edition.

Ausgewählte Beiträge zur Kinderpsychologie und Pädagogik, von G. STANLEY HALL. Translated by Dr. Joseph Stimpfl. O. Bonde, Altenburg, 1902. pp. 454.

This is volume four of the international library of pedagogy and its auxiliary sciences, and may be followed by another volume. Dr. Stumpfl has here translated thirteen of Dr. Hall's papers. These are the Study of Children, Children's Lies, Contents of Children's Minds on Entering School, The Story of a Sand Pile, The Love and Study of Nature, Research, the Vital Spirit of Teaching, The New Psychology as a Basis of Education, The Ideal School, Some Aspects of the Early Sense of Self, A Study of Fears, and others. Several of these have been annotated by the translator who has also written an introduction of twenty-two pages giving some sketch of child study in America.

1. The Survival Values of Play. 2. A Statistical Study of Education in the West, by HARVEY A. CARR. Investigations of the Department of Psychology and Education of the University of Colorado. Vol. 1. No. 2. Boulder, Colo., Nov., 1902. pp. 78.

In the second of these studies, the author finds that as compared to groups of States called by the Census Bureau, North and South Atlantic, North and South Central and West, the latter, although the proportion of children to the population is lower than in any other section, is first in proportionate attendance and in financial equipment and proportionate support; first, in the requirements in English and History in the high school and the average length of its course and in higher education; first, in attendance of students residing in the division and in the proportionate number of such students. In other respects, it is second, third, etc.

In the first paper, Mr. Carr gives us a valuable discussion of the play question. He inclines to the survival view rather than the practice theory of Groos. Among the rapidly growing literature on this subject, we must class this paper as one of the best.

The Hearts of Men, by H. FIELDING. Hurst & Blackett, London, 1901. pp. 324.

This book is by no means a sequel to the author's notable "Soul of a People." It discusses some 30 different topics involving the nature of religion; its use; optimism and pessimism; miracle; after death; Sunday; prayer; men's faith and women's faith; God; the sacrifice and the mother; enthusiasm; heaven; the way of life; theology, etc. Although well read this author's great charm is in the wide personal experience from which he draws his material and his unique though somewhat unsystematic style.

Die Entstehung der ersten Wortbedeutungen beim Kinde, von ERNST MEUMANN. Leipzig, 1902. pp. 69.

We have here a valuable study of the development of the first mean-

ing attached to words by children. The writer has made good use of American, English and other authorities, and has shed real light and brought some progress to our knowledge of the early thinking and speaking of children.

Die Seele des Kindes nebst kurzem Grundriss der weiteren psychischen Evolution, von DR. J. A. SIKORSKY. Leipzig, 1902. pp. 80.

The writer first treats of the soul of the new-born child, then, at the age of three months, on the basis of tests of tactilogical and acoustic sensations with interesting remarks on feeling, knowledge, and neuro-psychic hygiene. He discusses more briefly the period from the 4th to the 10th month, from the 1st to the 2d year, and more fully from the 2d to the 6th year, with brief remarks on youth.

Child Culture According to the Laws of Physiological Psychology and Mental Suggestion, by NEWTON N. RIDDELL. Chicago, 1902. pp. 129.

The author is lecturer on heredity, psychic phenomena, inspiration, brain building and soul growth. His book is the work of one who, it would appear, has either never heard of Wundt, Höffding and the rest, or has no use for them. There is extremely little in this work that suggests physiological psychology in the sense of these writers, but the author believes in moral training, ideals, reverence, purity, the home influence, energy, and reason; but disbelieves in tobacco, domineering on the part of parents, partiality, etc.

Psychologie der Naturvölker, von FRITZ SCHULTZE. Leipsig, 1900. pp. 392.

This author seeks to prove that "the psychology of wild men is not wild psychology." To control savages, the German way is to educate them. The author has read very widely, and divides his subject into thinking, willing, and the religious views of natural men. In an appendix he gives an interesting digest of Sutherland's "Evolutionary Ethics" which appeared just after his own work was published, and which he enthusiastically approves.

Mind in Evolution, by L. T. HOBHOUSE. The Macmillan Co., New York, 1901. pp. 415.

This important work is described as an analysis. Its chapters are—mind as a factor in evolution, organic adaptability, reflex action, instinct, assimilation and readjustment, concrete experience and the practical judgment, learning among the higher animals, the method of trial and error, some experimental results, knowledge of concrete objects, articulate ideas, intelligence and the social instinct, the concept, products of conceptual thought, systematic thought, summary of the stages of correlation, organization, conflict and evolution, self conscious development.

Analystes et Esprits Synthétiques, par FR. PAULHAN. F. Alcan, Paris, 1903. pp. 196.

These two are the great movements of the human spirit to which all psychic operations submit. Different types of each are described, their qualities, defects and excesses, and the mean is found in an equilibrium between them.

Esquisse Psychologique des Peuples Européens, par ALFRED FOUILLÉE. Paris, 1903.

This is a study of national character with chapters each for Greeks, Italians, Spaniards, the English people, Germans, Russians, French, and the Neo-Latins.

Le Caractère, par D. MALAPERT. O. Doin, Paris, 1902. pp. 305.

After characterizing ethology, its object and its method, the author passes to discuss the factors of character, and metaphysical theories concerning it; those of temperament, and psychological theories concerning it; classification; and concludes with a chapter on the morbid and abnormal traits and characteristics.

Nineteenth Annual Report of the Bureau of American Ethnology. 1897-98. Parts 1 and 2. Govt. Print, Washington, 1900.

This report shows no sign of falling below the high standard always maintained by these publications, which are a great credit to American scholarship and to the liberality of our government. Among so many interesting papers it seems invidious to single out any for special mention, but certainly all will be interested in J. W. Fewkes's Tusayan Flute and Snake Ceremonies, and in his investigations of the migrations of the same tribe, and in Mr. Jenks's Wild Rice Gatherers of the Upper Lakes. The study of clans, which constitutes a large portion of the other volume, is also of a high degree of value and interest.

Les Obsessions et la Psychasthénie, par PIERRE JANET. Paris, 1903.

This elaborate work first analyzes symptoms classified under obsessive ideas, forced agitations, psychasthesic stigmata. The second part is on the general abatement of psychic tension, and first treats of psycho-genetic theories of evolution and diagnoses the treatment of the place of psychasthenia. The work follows the method of his previous book on Forced Ideas.

Psychopathological Researches. Studies in Mental Dissociation, by BORIS SIDIS. Published under the auspices of the Trustees of the Psychopathic Hospital, Department of the New York Infirmary for Women and Children. G. E. Stechert, New York, 1902. pp. 329.

This is a collection of studies by Dr. Sidis and his assistants, W. A. White and G. M. Parker. The chief topics are mental dissociation in functional psychoses, in alcoholic amnesia, in psychic epilepsy, in depressive delusional states, in functional motor disturbances and in psycho-motor epilepsy. The few typical cases here studied were selected from a mass of material, and the effort is to avoid theories and give résumés, the conclusions being reserved for another work, promised soon, entitled Principles of Psychology and Psychopathology.

Les Obsessions et les Impulsions, par A. PITRES et E. RÉGIS. O. Doin, Paris, 1902. pp. 434.

This work treats first of obsessions, impulsive and ideational; hallucinations; phobias, their cause, progress, duration, prognostics, diagnostics, and treatment. The second part is devoted to the impulses.

Zur Psychologie und Pathologie sogenannter occulter Phänomene, von C. G. JUNG. Leipzig, 1902. pp. 121.

This young Zurich psychiatrist first discusses an interesting case of somnambulism in a spiritual medium. Then passes to the development of somnambulic personality, hemi-somnambulism, automatism, hallucination, change of character, relation to hysterical attack and the patient's speech, etc.

Martineau's Religionsphilosophie, von ORLO J. PRICE. Newark, O. pp. 103.

American students of philosophy abroad are doing a good service in

spreading knowledge of American and English systems by choosing for the topic of their dissertations brief presentations of home writers. This is a good illustration of its class.

Theology and the Social Consciousness. A Study of the Relations of the Social Consciousness to Theology, by HENRY C. KING. The Macmillan Co., New York, 1902. pp. 252.

Under the real meaning of the social consciousness for theology are treated, its definition, the inadequacy of analysis to the organism, the ethicizing of religion, and the emphasis upon the historical element. Under the influence of the social consciousness upon theological doctrine are treated, the influence of the deepening sense of the like-mindedness of men upon theology, of the mutual influence of men upon it, and the value and sacredness of the person.

The Psychological Elements of Religious Faith. Lectures by Charles C. Everett. Edited by Edward Hale. The Macmillan Co., New York, 1902. pp. 215.

This book is a response to the wish of Dr. Everett's friends that there should be some permanent record of his lectures on theology, the character of which is unique and has made a profound impression. As he left no manuscripts, recourse was had to notes of students. His theological instruction was divided into two courses. The shorter one was on the psychological elements of religious faith. This is comprised in the second volume and is to be followed by another containing the longer course on the subject content of religious faith.

An Essay on Laughter; Its Forms, its Causes, its Development, and its Value, by JAMES SULLY. Longmans, Green & Co., New York, 1902. pp. 441.

The chief chapters are the Smile and the Laugh; Occasions and Cause of Laughter; Varieties of the Laughable; Theories of the Ludicrous; Origin of Laughter; Its development in the First Three Years; the Laughter of Savages; Laughter in Social Evolution; in the Individual or Humor; in Art or Comedy; with a final chapter on the Ultimate value and Limitations of Laughter.

La Mimique, par ÉDOUARD CUYER. O. Doin, Paris, 1902. pp. 366.

The chief chapters are on the muscles of the head; the analysis of expressive movements in face, head, trunk, upper and lower limbs; and finally the synthesis of expressive movements is devoted to characterization of half a dozen feelings and sentiments. There is little attempt at original work and little novelty.

Allgemeine Æsthetik, von JONAS COHN. W. Engelmann, Leipzig, 1901. pp. 293.

The writer treats the content of the field of æsthetic worth, its significance and its limitations, with various subordinate chapters.

The Sensation of Pain and the Theory of the Specific Sense Energies, by ANNA J. MCKEAG. (Experimental Studies in Psychology and Pedagogy, edited by Lightner Witmer.) Ginn and Co., Boston, 1902. pp. 87.

After an analysis of the pain judgment, chapters follow on general judgment, qualitative distinctness and directness, on pain judgment and judgments of other sensations. Part two is devoted to the stimulation of pain, and part three, to an account of pain as a specific differentiation of sense.

Essays Historical and Literary, by JOHN FISKE. 2 vols., pp. 422 and 316. The Macmillan Co., New York, 1902.

These two sumptuous volumes are a pleasure to handle. The material of the first volume was intended to be embodied in a larger work called A History of the American People. Many of the chapters were given as lectures and most had been printed before. The topics are: Thomas Hutchinson, Charles Lee, Hamilton, Jefferson, Madison, Jackson, Harrison, Tyler, Webster, Milton, Huxley, Tyndall, Spencer's service to religion, the Boston Tea Party, Old and New ways of Treating History, the Fall of New France, Evolution and the Present Age, and Koshchei the deathless.

Shakespeare's Portrayal of the Moral Life, by FRANK CHAPMAN SHARP. Charles Scribner's Sons, New York, 1902. pp. 232.

This book is dedicated to Professor Garman, and its chapters are a study of motives, transcendentalism, the criterion of right and wrong, the nature of the good, conscience and the conscienceless, the freedom of the will, virtue and happiness, ethics and metaphysics. It is unfortunate that the author has limited his survey to dramas put in their present form after the close of 1600.

The Mind of Man; a Text Book of Psychology, by GUSTAV SPILLER. MacMillan & Co., New York, 1902. pp. 552.

In the preface we are told that every portion of each chapter is the outcome of research. In the first part, entitled Method, chapters discuss systems as distributed, as organized, as need-satisfying, as redeveloped, as need-determined, and as unified. Part Second, General Analysis. Part third is entitled, General Synthesis, and discusses systems as individualized, classified, and as attention determined.

Grundzüge der physiologischen Psychologie, von WILHELM WUNDT. Vol 2, pp. 686. W. Engelmann, Leipzig, 1902.

The second volume of this thoroughly revised fifth edition contains 153 cuts and 686 pages. As this is probably the last revision of the chief work of the leading modern psychologist, it will long be a standard, and, of course, should be in the possession of every one interested in the subject.

Outlines of Psychology, by WILHELM WUNDT. Second edition. W. Engelmann, Leipzig, 1902. pp. 390. Price, $2.00.

This second English edition includes all that the author has incorporated in the fourth German edition. There are some twenty places which have been more or less extensively rewritten. The work is now a compact and tasteful volume and includes a transcript of Wundt's most important conclusions.

Lehrbuch der Psychologie, von DR. WILHELM JERUSALEM. Wien und Leipzig, 1902. pp. 213.

This handbook follows the general topic of knowledge, feeling and will with a brief appendix on sleep, dreams, hypnotism, and speech disturbances. It is empirical although it lays little stress upon experimental subject matter.

Beiträge zur Psychologie und Philosophie, von GÖTZ MARTIUS. Erster Band, 3. Heft. W. Engelmann, Leipzig, 1902.

Martius's studies are infrequent but very welcome. The present number contains an article by the editor on the duration of light sensations, and another by Hüttner on the psychology of time consciousness with continuous light stimulations.

The Force of Mind or the Mental Factor in Medicine, by ALFRED T. SCHOFIELD. P. Blakiston's Son and Co., Philadelphia, 1902. pp. 309.

Studies from the Yale Psychological Laboratory, edited by E. W. Scripture, Ph. D. Vol. 10, 1902. Yale Univ., New Haven, Conn.

This number of Dr. Scripture's studies contains the following articles: Researches on Rhythmic action, by Ishiro Miyake; researches in experimental phonetics, by E. W. Scripture; experiments on motor education, by W. S. Johnson; involuntary movements of the tongue, by H. C. Courten; phonetic notation, by E. H. Tuttle.

A Dream of Realms Beyond Us, by ADAIR WELCKER. San Francisco, 1902.

This author attempts the modest step of telling us what comes after religion and philosophy and to tell "that which no method of philosophy has yet had in it." It "will create a new vision within earth and cause peace upon earth to come." It is designed to put into the world "that act of the endless world art that will so touch the souls of men that into them will be caused gradually to come from this time on perception and a knowledge of the meaning and purpose of things." Thus "highest manhood in the form of conscience will be caused to come down and to be and dwell upon earth."

Was ist Raum, Zeit, Bewegung, Masse? Was ist die Erscheinungswelt? von JULIUS VON OLIVIER. L. Finsterlin, München, 1902. pp. 153.

The author really offers us here in his greatly enlarged edition a brief system of philosophy, which is evidently the result of a great deal of careful thought. It certainly has a great merit of condensation.

Substanz und Causalität bei Berkeley, von LOUIS A. FREEDMAN. (Dissertation.) Strassburg, 1902. pp. 53.

Earthquakes; Their Origin and Phenomena, by WALTER HALE. 1902. pp. 22.

This writer deliberately takes the view that earthquakes and volcanoes are caused not primarily by internal disturbances in the body of the earth, but by the impact of comets and other invisible bodies striking and plunging into the earth.

L'Association des Idées, par ÉDOUARD CLAPARÈDE. O. Doin, Paris, 1903. pp. 426.

The first part of this book discusses the mechanism of association, its conditions, force, *enchaînement*, form and rapidity. The second part confines the discussion to the mental life, its associations, in sense, memory, intellect and activity.

La Volonté, par FR. PAULHAN. O. Doin, Paris, 1903. pp. 323.

The chapters here are will and automatism, will and suggestion, psychic general facts, the act of will, its evolution from caprice, its domain, its extension, the will spirit from the physiological and the social point of view.

Unitarianism in America; A History of its Origin and Development, by GEORGE WILLIS COOKE. American Unitarian Association, Boston, 1902. pp. 463.

Perhaps no one is more competent to write this interesting history than Mr. Cooke. It is a most inspiring theme, the leaders of which have been among the pioneers in education, reform, charities, states-

manship, literature, and higher criticism. It is a comprehensive, thorough and interesting story told by one who is perhaps as competent as any one in the ranks to deal with such a theme.

Progress in the Clinical Study of Psychiatry. The Study of Principles in Their Application to the Classification of Insanity, by EDWARD COWLES. Reprinted from The American Journal of Insanity, July, 1899.

Treatment of Paresis: Its Limitations and Expectations, by Edward Cowles. Reprinted from the American Journal of Insanity, April, 1902.

Hallucinations and Illusions, by George T. Tuttle. Reprinted from the American Journal of Insanity, January, 1902.

On Certain Studies with the Ergograph, by August Hoch. Reprinted from The Journal of Nervous and Mental Disease. pp. 9.

On the Clinical Study of Psychiatry, by August Hoch. Reprinted from The American Journal of Insanity.

Eighty-Eighth Annual Report of the Trustees of the Massachusetts General Hospital Concerning the McLean Hospital at Waverly, 1901. Barta Press, Boston, 1902. pp. 128.

It is impossible to do justice in the space at our disposal to the extremely valuable work in the study of abnormal and morbid psychology, which this country owes to the initiative of Dr. Edward Cowles, for many years the head of the McLean Hospital and the constructor of the new buildings which make it distinctly the finest in the world. This writer was the leading pioneer in the movement for the training of nurses for the insane and founded the first school. He was one of the first in the country to appreciate the importance of the new or experimental psychology in this work, and nearly twenty years ago took six months off at Baltimore and wrote a memorable and classic study of a case of paranoia. Careful and systematic clinical work has for many years been a specialty at McLean. Now in this institution we find provisions for most careful chemical analyses, for brain pathology and for experimental work, so far as these shed light upon alienation.

We have in the above articles, all of them valuable contributions, specimens of the work done at this institution. Dr. Hoch is one of the best trained and careful workers in his field in the country, with a thorough knowledge of the best that is done and known in Europe; while Dr. Tuttle is perhaps no less expert in clinical work. On the whole, such a unique and harmonious combination of scientific research and of efforts toward more effective and curative care of patients, where each helps the other, has probably never before been made.

Bulletin de la Société libre. Schleicher Freres. Paris, 1902. pp. 200.

The Bulletin de la Société libre pour l'étude psychologique de l'enfant has just completed its second year—eight bulletins having been published. Its avowed object is to further child study from both the pedagogic and purely scientific points of view. It issues questionnaires, collects scientific information and solicits communications from all sources on either individual or collective observations relating to the psychology of childhood. It includes in its bureau of direction The. Ribot, A. Binet and M. F. Buisson, Director of Public Instruction. Edited by Schleicher Freres, rue des Saints-pères 15.

The Hibbert Journal. A Quarterly Review of Religion, Theology, and Philosophy. Vol. I, No. 1. Williams and Norgate, London, 1902. pp. 208.

This stately review is unusually attractive in form. The print of the larger articles is excellent, and the edges are trimmed, something which ought to be required by law in all journals and books, because many are really not worth cutting, and some good matter is lost to those who want it because of the drudgery that is necessary to cut the leaves and to find the place when the edges are rough, so that it cannot be readily thumbed through. The articles are by Percy Gardner on the bases of Christian doctrine; Josiah Royce on the concept of the infinite; the outstanding controversy between science and faith, by Sir Oliver Lodge; Matthew Arnold, by Stopford A. Brooke; "Righteousness of God" in St. Paul's Theology, by James Drummond; early doctrinal modifications of the Gospels, by F. C. Conybeare; catastrophes of the moral order, by (I) G. H. Howison, (II) R. A. Armstrong, (III) R. F. Horton. Nearly one-third of the number and one-half the matter is taken up by reviews of well selected books by eminent writers, and the contents of recent philosophical and theological journals are appended.

The Religion of a Mature Mind, by GEORGE A. COE. F. H. Revell Co., Chicago, 1902. pp. 442.

The writer thinks that the heart of modern man is hungry for a fresh original experience of the Divine, which is something more than a mere reconstruction of doctrine. The personal religious life needs reorganization, for man has come of age. There is a close kinship between human nature and Christianity, which ought to be most scientific, ethical and modern. Christian life must simulate modern progress without sacrificing the inheritance of the past and must assume the immiuence of God. Perhaps the best of the thirteen chapters are those entitled modern manhood, the scientific spirit in matters of religion, the moral foundations of spirituality, the breadth of religious experience, the life of prayer.

Religionsphilosophie, von HARALD HÖFFDING. O. R. Reisland, Leipzig, 1901. pp. 369.

The author first discusses the theory of knowledge and its relations to the philosophy of religion. The subject is then treated from a psychological standpoint, including the relations between religious experience and faith, the development of the religious concept, dogma and symbol, the principle of the preservation of worth and of personality. The last part discusses the philosophy of religion from the ethical standpoint.

Can Telepathy Explain? Results of Psychical Research, by MINOT J. SAVAGE. G. P. Putnam's Sons, New York, 1902. pp. 243.

The author does not quite call himself a spiritualist, but he is "strongly inclined to hold the belief in continued personal existence as capable of proof and in the possibility of an at least occasional communication." From this standpoint, he treats the work of the Society for Psychical Research, which he thinks is growing respectable; clairvoyants, apparitions, levitation and telekinesis; gives many fugitive facts; and has certainly written a very readable book, unconvinced as it will leave many who would willingly believe.

Atti dell' XI°. Congresso della Società Freniatrica Italiana. Ancona, 1901. Riv. Sperim. di Fren. (Reggio i. E.), Vol. XXVIII (1902), pp. 1-490. Especially 331-455.

The seventh session (morning of Oct. 3, 1901) of the eleventh Congresso della Società Freniatrica Italiana, held at Ancona, was devoted to the subject of "The Practical Direction which psychiatry can give to Pedagogy." The paper was read by Professor Cesare Agostini of Perugia and discussed by Drs. Montesano, Del Greco, Bianchi, Obici, etc. The present system of education, is itself one of the most important factors of mental disease, since it devotes itself almost entirely to an intensive cultivation of the intelligence, without a corresponding physical and moral education. Bonfigli was right in saying that defective education in childhood, particularly in relation to the evolution of the moral sense and the formation of character, is one of the most powerful social factors of mental alienation. The school has been long enough under the illusion that by instruction a character can be created out of hand, a process leading only to mental decadence. The psychiatrist, who not only studies the anomalies and the diseases of mind, but seeks, as far as possible, to prevent them, from the opportunities he has had of observing the evil effects of imperfect and erratic pedagogical ideas upon the mental health of children, can suggest to the teacher the practical norms by which he can recognize and remove in time the bad results of excessive and untimely mental work, particularly in those who, for hereditary and pathological reasons, are predisposed to disturbances of the intellect, feelings and will. Instruction must be fitted to the development and the mental capacity of the child, to the degree of sensitiveness, to the power of instincts and emotions. The normal education of those senses must be facilitated which directly influence intellectual and moral development and make for character. For real intellectual and moral education a proper basis of physical education must be provided and a normal evolution with a physiological validity of the cerebral activities established. To do this the teacher must know something about children in general and about his pupils in particular. He must know the general facts and conclusions of psychology and anthropology, normal and pathological, and must have the assistance of a medical inspector, preferably of psychiatrical training and experience, who will be able to detect in their early stages those anomalies and defects, mental and physical, which, if not at once attended to, will endanger in later life the health or the sanity of the pupils concerned. Thus oriented from the practical experience of psychiatry, pedagogy will be better able to go about its task of preparing the individual, according to his psycho-physical aptitudes, for activity in the various branches of science, art and industry having made him more fit to survive in the struggle for life and more capable of profiting by his social environment.

In the discussion Dr. Bianchi wisely said that the attempt to create an absolute norm by physical diagnosis and anthropometric evidence and to infer from such data moral disposition, etc., was fraught with great danger, for many who presented numerous and marked stigmata of degeneration are endowed with intellectual powers and moral qualities superior to those of individuals much better constituted physically. A mediocre knowledge of physiology and psychology is a dangerous equipment for a teacher, and perhaps, after all, the medical inspector should be the diagnoser.

Dr. Obici emphasised the necessity for educating the sexual instincts, a matter which he and Dr. Marchesini have already treated in their book on collegiate loves and friendships.

At the time of puberty sexual instinct and emotions have a chief rôle in the formation of the morals and social feelings of the individual. The bad education of puberty is responsible for many of the "orgies" of love.

Dr. Obici also read a paper on "The Influence of Prolonged Intellectual Labor and Mental Fatigue upon the Respiration," which is to be published in full in a future number of the Rivista. His chief conclusions are that prolonged mental labor (arithmetical calculation) produces great irregularities of respiration, increases its frequency, induces more numerous and intense variations in depth, and decreases the length of the inspiration and of the post-inspiratory pause, increasing the duration of the expiration and its pause.

The rest of the morning and the eighth session (afternoon of Oct. 3) of the Congress were occupied with the consideration of "Criteria and Methods for the Educability of Defectives and Dements." The paper was read by Dr. De Sanctis, the well-known alienist and psychologist, who spoke with some detail of defectives (pathogenesis and classification of the feeble-minded, their educability), means and methods of education, etc. Dr. De Sanctis's chief conclusions are: All such defectives are potentially anti-social, and at certain times of their life most of them actually become so. There is no doubt as to certain intellectual and moral educability upon a scientific basis of most of these defectives. But the degree of educability is very variable, and intellectual and moral educablity are not always on the same level. Neither follows always a straight line of continuous improvement, but undergoes often retardations, arrests and regressions. Other than biopathological factors limit in some cases the degree of educability, and act unfavorably upon the ascending line of educational progress. The anti-sociality of so many of defectives is due to the arrest which so often takes place at the end of childhood or during adolescence. Factors contributing to this are the initiation of the struggle for life, diminution of family supervision, possibility of intoxication (alcoholic especially), readiness of criminal suggestions, development of nervous and mental diseases peculiar to adolescence, and most powerful of all, puberty and the awakening of the sexual instinct. Defectives and feeble-minded must be protected in adolescence and in youth,—and for them, as for normal individuals an "integral" education is justly demanded. There is but one efficacious means of education, *work*. This is to be applied in diverse forms according to the age, bio-pathological conditions, family relationship and social conditions of every individual defective. Farm-colonies, industrial schools, distribution of defectives among the families of farmers in the open country, etc., are all of value. The principle of individual education must be above all adhered to.

In his interesting article on "'Mental Tests' in the Schools," Dr. Ugo Pizzoli, the director of the Crevalcore Laboratory of Scientific Pedagogy, gives an account of a piece of apparatus devised by him for mental and psycho-physical tests. By means of this instrument, the chief part of which consists of five rectangular metal plates, whose serrated edges come into contact in such a way as to form figures containing all the graphic elements of writing (straight lines, curves, horizontal, oblique and vertical lines, angles, etc.) the pupil with pencil, electric attachment, etc., can go through the psychic actions and motor activities involved in the elements of writing. The records thus obtained serve for both normal and defective children a new and valuable "mental test." By means of this instrument "pre-education" in writing is possible. The apparatus educates the eye of the child and teaches him to co-ordinate the muscles used in such exer-

cises. Its simplicity, adaptability and variability make this apparatus a distinct aid to graphological education. By means of this new pedagogical appliance kindergarten pupils have learned to write in 15 days, as compared with a month by the old method. Comparing the writing, after five months of school of these two sets of children that of those who used the new apparatus was found to be much better. It would appear that Dr. Pizzoli's device could be made use of much in elementary education. A. F. CHAMBERLAIN.

A Plan for the Study of Man with reference to bills to establish a laboratory for the study of the criminal, pauper, and defective classes, with a bibliography of child study, by ARTHUR MCDONALD. Govt. Print, Washington, 1902. pp. 166.

This is an interesting and valuable outline in which the author abridges some of his old studies and adds new ones in order to show the great service which such a laboratory as he desires to establish could render. His persistent advocacy of this cause deserves great praise and is sure to be successful in the end.

Journal für Psychologie und Neurologie. Band I, Heft 1 & 2. J. A. Barth, Leipzig, 1902. pp. 88.

In this new journal, in which the Zeitschrift für Hypnotismus has been merged, we have first a general article by Forel on the justification of comparative psychology and its objects; then a long plethysmographic study with eight plates by Brodmann on the volume of the brain and forearm of men in sleep; a briefer study of muscle tonus with special relation to the cortex; and book notes.

Vom Fühlen, Wollen und Denken, von THEODOR LIPPS. J. A. Barth, Leipzig, 1902. pp. 196.

In this psychological sketch, three fundamental contrasts between feelings are characterized. Chapters are devoted to feelings of effort; the consciousness of reality; the laws of effort; feelings and endeavors conditioned by association; wishing, willing, and purposive activity; feelings of quantity and worth; the kinds of feeling relation; objective values and oughtness. No psychologist need be told that this long expected work is of the greatest value and acumen.

Annual Report of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1900. Report of the United States National Museum. Govt. Print, Washington, 1902. pp. 738.

In this report besides the report of the Assistant Secretary, head Curators, summary of operations, seven interesting papers are appended illustrating collections in the Museum, viz.: W. H. Holmes on anthropological studies in California; O. T. Mason on aboriginal American harpoons; A. E. Hippisley on ceramic art in China; C. K. Wead on contributions to the history of musical scales; Walter Hough on Hopi ceremonial pigments; Wirt Tassin on the gem and meteorite collections of the Museum.

Benoit de Spinoza, par PAUL-LOUIS COUCHOUD. F. Alcan, Paris, 1902. pp. 305.

The leading chapters are: the synagogue, the conversion, formation of the theory of substances, early writings, the principles of Descartes's philosophy, works on theology and politics and ethics.